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Effects of Thermal Additions on the Dynamics of Fouling Communities at Beaufort, North Carolina

by

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The experimental system itself altered the community of recruits by enhancing the recruitment of some species and by decreasing or eliminating the recruitment of other species. The permanent plate communities in the laboratory at a 0°C temperature differential were very different from those in the field, although both were composed of epifaunal species common in North Carolina.

Within the laboratory system, increasing temperatures had a pronounced effect upon recruitment of individual species and on some attributes of the permanent community, namely number of species and diversity. Increasing temperatures had little effect on the community type, which was dominated by the oyster *Crassostrea virginica* and the polychaete *Spirorbis borealis* in all temperature treatments. Temperature elevations of 2°C produced measurable effects on recruitment and percent cover by individual species. These effects were more apparent in the 4°C and 6°C treatments. Temperature effects were greatest at elevations of 6°C in midsummer when the 36°C temperature apparently exceeded thermal limits of many species. Caution is urged in extending these findings to the field or in using them for regulatory purposes. Consideration should be given to the specific limitations of the laboratory system in simulating the natural environment as well as the potential that certain temperature responses observed may be unique to this particular fouling community.

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SECTION 1

INTRODUCTION

The purpose of the investigation reported here was to determine the consequences of long-term, low-level elevations in temperature on the structure of the marine epifaunal (fouling) community at Beaufort, North Carolina. The project represents one approach to the investigation of sublethal consequences of thermal additions by estuarine and coastal power plants.

Large variations in temperature occur seasonally in coastal and estuarine waters in the mid-latitudes (temperate zone). Sessile organisms living in shallow, temperate, marine waters often have life histories which correlate closely with seasonal variations of water temperature. Life history phenomena can, in turn, be correlated with the thermal dependence of such physiological functions as metabolism, feeding, growth, reproduction. Descriptions of these functions, the results of both field and laboratory studies, have led to a large body of well synthesized information (e.g. Prosser 1973, Kinne 1970, Newell and Bayne 1973).

In the past investigations of the influence of temperature on marine communities (as compared to individual species) have centered mainly around descriptions of the importance of seasonal recruitment and annual fluctuations of the abundances of species comprising the community (Gunter 1957). Regarding epifaunal (fouling) marine communities, temperature variations have been investigated primarily as they result in increased growth and recruitment during warmer months (McDougall 1943, Osman 1977, Sutherland and Karlson 1977). Considerable literature concerning effects of temperature on marine communities has developed recently from investigations of unnatural thermal discharges from steam electric stations (Gibbons and Sharitz 1974; Esch and McFarlane 1976; Thorp and Gibbons 1979; Majewski and Miller 1979). Field studies have examined effects of thermal addition on marine communities including fishes (Carr and Giesel 1975; O'Connor and McErlean 1975; White et al 1977), soft bottom benthos (Warinner and Brehmer 1966, Blake et al 1976), fouling communities (Naylor 1965a; McCain 1975), and sea grasses (Thorhaug et al 1978), and coral (Jokiel and Coles 1974, 1977). Total estuarine ecosystem effects have been described by McKellar (1977). Such field studies have been very useful in understanding the effects of thermal additions in a general sense; however, it is often difficult from field studies alone to quantify the biological consequences of specific levels of thermal elevation, particularly those of a sublethal nature. A good record of the temperatures actually experienced in the field is rarely available. Yet quantitative information on thermal effects is important for power plant siting and design and for other environmental regulatory purposes.

Controlled laboratory studies have been undertaken for more precise examination of the relationships between elevated temperature and biological effects; most of these have tested single species. Yet the applicability of these results to the field often has been constrained by such limitations as the short duration of the study, the use of unusually high temperatures, an inability to test for full life cycle effects, or difficulties in predicting the community level consequences of such tests. A long-term laboratory study with a natural assemblage such as the fouling community is an approach that should overcome many of these limitations.

Wolfson (1974) conducted a laboratory study of the effects of temperature on a fouling community in which unfiltered seawater from coastal waters in southern California (Scripps Institution of Oceanography) was pumped through four aquaria in an open-flow system. Two aquaria served as unheated controls, one was maintained continuously at 3°C above ambient temperature, and the fourth was cycled with six-hour intervals at 3°C above ambient followed by six-hour intervals at ambient. Asbestos plates were suspended in the tanks in March and development of the fouling community was followed for one year. A diverse assemblage of epifaunal animals settled on the plates. Periodically information was collected on abundance, size, and reproductive state of species on the plates and species diversity was calculated. Wolfson (1974) found that the response of individual species to elevated temperature varied from positive to negative effects on recruitment and growth depending upon which species was considered. In the summer when water temperatures were highest, survival was reduced in a number of species. Species exposed to the cycling thermal additions were much less affected than those exposed to constantly elevated temperature. Species diversity of the communities in all treatments was similar in the spring. During the summer there was a decrease in diversity in both elevated temperature tanks. In the fall the diversity of the communities in the cycling temperatures was similar to that in the ambient temperature treatment, but diversity in the constantly heated water remained depressed. The results of these experiments by Wolfson (1974) were similar to what had been noted previously in field studies; however, his experiments were of short duration relative to the time for complete fouling community development and they did not address community changes caused by the experimental system (in the absence of thermal additions). Moreover, seawater temperatures in southern California cycle over a range of approximately 12°C (12°C - 24°C), while temperatures of the bay and estuarine waters along the mid-Atlantic cycle over a range of 5°C - 30°C.

The Beaufort, North Carolina, community selected for the study reported here was originally described by McDougall (1943), and detailed investigations of the structure and function of the community have been reported in a series of recent publications (Sutherland 1974, 1977, and 1978; Sutherland and Karlson 1973, 1977; Karlson 1978). McDougall (1943) identified 69 common pile-dwelling animals in Beaufort, North Carolina in a study of recruitment and community development in relation to water depth, season, light, water current, substrate type, and orientation, and drew the following conclusions:

(1) Many species were confined to or were most abundant at a specific level (depth) on a vertical surface.

(2) In studies of the reproductive condition of 21 species, there were 19 species in breeding condition in July, August, or September; five species

in January, February, or March; and two species during nine months of the year.

(3) There was intense competition for space and frequent sloughing off of organisms, creating new open space for recruitment of new individuals and new species.

(4) Light, current velocity, substrate type, and substrate orientation all influenced the species composition in the community.

Sutherland (1981) investigated biological interactions in a fouling community at Beaufort over an eight-year period. He defined his community as the group of organisms developing on the lower surface of unglazed ceramic tile plates (232 cm^2) which were suspended horizontally 0.3 m below low tide in racks beneath the Duke University Marine Laboratory dock. All these communities developed under similar conditions which allowed investigation of the resultant community structure relative to the date of initial submergence of the substrate (Sutherland and Karlson 1977) and investigation of the functional role of dominant species (Sutherland 1978). Sutherland (1977) restricted his investigations to "foundation species" which he defined as: (1) those species capable of occupying primary space (attaching to the plate itself), ruling out motile species and those species seen only attached to other species; (2) those species which at some time during the experiment occupied at least 10 percent of the primary and/or secondary (epizoic) space on any one plate. Using these restrictions, the tile plate community was composed of 21 of the 69 common species sampled by McDougall (1943). This community (Sutherland and Karlson 1977) is considered to be a well-defined subset of the total sessile marine invertebrate community as described by McDougall.

Some of Sutherland's findings (as referenced above) which are related to the present study may be summarized as follows. The epibenthic community which initially develops on bare substrate is entirely dependent upon when the substrate is first submerged in the water. Thus substrates submerged at different months or at the same month in different years can develop very different communities. Once a community has developed, some species apparently are excluded from recruitment by other species already present. Within a community some species are better competitors for space than others. In most communities periodic sloughing off of groups of animals provides unoccupied space for recruitment of the larvae of species which happen to be present and ready to settle at that moment. Most species are short-lived and show seasonal variations in abundance as recruiting larvae or as established adults, or both. Unlike many intertidal epibenthic communities, there is rarely a competitive dominant in this fouling community; and when one species is dominant, the dominance seldom lasts more than one year. Succession in the classical sense does not occur. The only predictable community descripter for these systems was that an equilibrium number of eight to ten species per plate was often observed.

Because Sutherland's community (Sutherland and Karlson 1977) was considered amenable to experimental treatment in the laboratory, it was chosen for the present study to investigate the long-term effects of low-level thermal additions on larval recruitment and community development. This community was especially attractive because the sizable amount of information already available on field-developed communities would allow an assessment of the effects of the laboratory system and thermal additions on community structure. The experiment described here was designed to evaluate, in a flow-through laboratory system, some of the ways in which low-level thermal additions may alter community structure, and to provide additional insight into the consequences of long-term, low-level thermal additions to estuarine and near-shore coastal waters.

SECTION 2

CONCLUSIONS

Long-term, low-level thermal additions had dramatic effects upon some parameters of recruitment and community structure of fouling communities but had little influence upon other parameters. Within the laboratory system, increasing temperatures resulted in a complex of effects.

The direction and magnitude of the effects on recruitment of species were not often the same as those observed for percent cover by the same species on permanent community plates. A 2°C differential in temperature resulted in significant differences in recruitment of individual species in an average of 40.7 percent of the cases where significant recruitment occurred. Significant recruitment is defined as an average of 10 or more individuals per plate in one or the other of the treatments being compared. This effect increased to 53.5 percent at the 4°C differential and 62 percent at the 6°C differential. The significant differences in recruitment were both positive and negative and often depended upon the species, the treatment, the time of year, and the year itself. For example, the number of individuals recruited increased in each elevated temperature treatment for Bugula neritina and Spirorbis borealis and decreased for Schizoporella errata and Balanus spp. (+2°C and +4°C only). From the community standpoint increasing temperature did result in a decrease in the average number of species recruited in the summer and an increase in winter. No temperature effect upon the community structure of recruits was detected by cluster analysis of the average number of individuals recruited by each species for each treatment for the 29 sequential time periods.

On the permanent community plates, the average number of species and diversity decreased with increasing temperature; this effect was particularly evident when comparing 6°C with 0°C plates in midsummer. Cluster analysis of the percent cover data for permanent plate communities did not show a temperature effect on community structure. This result is due mainly to the dominance of Crassostrea virginica and Spirorbis borealis on the community plates in most temperature treatments. Cluster analysis is not a good technique for distinguishing thermal treatment effects in communities of this type, since the species clusters are most affected by the presence or absence of the dominant species and their relative (not absolute) abundance.

A comparison of field results with those obtained in the laboratory in the 0°C treatment (tanks with no thermal addition) indicated that the laboratory system itself had a large effect upon recruitment of most species and the development of the communities. Recruitment of species on field plates and laboratory 0°C treatment plates was significantly different in 76 percent of the 270 cases analyzed. The pattern of these differences was complex and varied through time; there were positive, negative, and neutral effects on the number of individuals recruited. Species composition of the community as determined by cluster analysis of percent cover data also differed, with only one species (the oyster Crassostrea virginica) being a significant member of both field and laboratory 0°C communities. The percentage of unoccupied space was significantly greater on laboratory 0°C plates than on field plates. However, the number of species per plate and the diversity, based on percent cover data, were similar for field and laboratory 0°C plates. Although the community composition differed, all species in both communities were common members of the epibenthic community in North Carolina.

Some of the differences between the laboratory and field communities may have resulted from ingestion of larvae by suspension feeders in laboratory communities, as there was a large decrease in suspended material in laboratory tanks relative to that in the field. Analysis of flow rates, chlorophyll a values, and rates of suspension feeding by communities suggested that the system was probably food stressed during the warmer months of the year in all temperature treatments and throughout the year at the 6°C differential. The laboratory system also incompletely simulated the field in other ways, including the absence of strong currents, rapid turnover of water, and pelagic predators, plus the potential for loss of some larval recruits and food due to damage by pumping or ingestion by any fouling organisms in the seawater lines.

In this study a chronic 2°C elevation in temperature had measurable effects on some parameters of community development (e.g. suppressed or enhanced recruitment for some species). Increases of 4°C and 6°C caused similar, but more pronounced effects. At 4°C, species number on the community plates was reduced during all seasons. At 6°C species number and diversity were reduced markedly, particularly in the summer and autumn months after ambient temperatures were the highest. These findings should be applied with caution to field or regulatory questions concerning the consequences of thermal additions, recognizing the limitations of the experimental systems. Recruitment of larvae and their subsequent growth and survival were probably influenced by the experimental system, in some ways positively and in others negatively. The limited food supply in the system doubtless compromised growth and possibly survival of the oyster, one of the two community dominants. Yet, given careful interpretation, these results do illustrate some of the ways in which long-term, low-level thermal addition may alter population and community structure of a warm temperate zone biota.

SECTION 3

RECOMMENDATIONS

This study highlights two issues which should be considered when assessing the consequences of thermal addition for estuarine and coastal communities. First, conspicuous effects are most likely to occur during the season in which water temperatures are naturally at their maximum. To predict allowable thermal additions during this period, an estimate of the long-term, incipient upper thermal limit should be experimentally determined for the communities of concern. If community studies are not practical, studies should be conducted for the community dominants. Secondly, during seasons in which the community upper thermal limit would not be exceeded, subtle changes may nonetheless occur. Very low-level thermal additions (e.g. 2°C) may have little effect other than increasing the duration and the intensity of community spawning and recruitment. Higher levels of chronic additions (e.g. 4°C or 6°C) may alter community structure, as evidenced here by reductions in species number and community diversity. The long-term implications of such changes for community integrity or for the protection of populations of particular concern will require further investigation of the communities or species in question.

Marine epibenthic communities hold potential as a research tool to investigate the long-term effects of sublethal environmental stress, including anthropogenic perturbations of a conservative or non-conservative nature. These communities develop readily on clean surfaces, they integrate natural changes in environmental conditions, and their species composition may be ascertained easily in a nondestructive fashion. Interaction among species is simple; it is predominantly competition for primary space.

However, there are some problems which must be resolved when employing the fouling community in experimental studies. The problem of providing adequate food may be addressed by increasing the water exchange rates, assuring that seawater delivery lines are free of fouling organisms, and minimizing the biomass in each experimental tank. Maintenance of a strong current within the tanks may also be considered, as this will enhance the development of additional species typical of this community. Other conditions normally experienced by this assemblage are difficult to simulate in the laboratory, such as the presence of predators. In order to address community questions, it may be necessary for the study to be conducted for more than a year, since the epibenthic community which is initially established may have only one dominant, with a monoculture resulting. Given additional time, the assemblage usually moves towards increased diversity.

Experimental studies on communities should employ multiple parameters to describe community structure and development. In this research, one parameter of community structure was percent cover. No treatment effects were evident for this parameter by cluster analysis. However, cluster analysis is considered to be a relatively insensitive technique for a community having only two dominants. In contrast, other community parameters, such as diversity using percent cover data and percent unoccupied space, did show significant influence of thermal additions. In addition, it is important to recognize that an environmental stress (either natural or anthropogenic) may have a negative influence on one species or characteristic of a community, a positive effect on another, and no effect on a third.

SECTION 4

METHODS

LOCATION

The experiments described in this report were carried out at the Duke University Marine Laboratory, Beaufort, North Carolina. Beaufort is located on the Atlantic coast, southwest of Cape Hatteras, North Carolina, and the Duke University Marine Laboratory is located near Beaufort in the Newport River estuary approximately one mile from the Atlantic Ocean.

The marine organisms of this area (Carolinean Province) represent a mixture of northern and southern temperate species with greater affinities to the subtropical Caribbean Province than to the colder Virginian Province to the north. Normal water temperatures range from a low of 3°C - 5°C in late January and early February to a high of 30°C in late July and August. Salinity generally ranges from 30 - 35 parts per thousand with occasional lower values after heavy rains. There are diurnal tides, normal for the east coast of the United States, with a range of 1 - 2 m depending upon the phase of the moon and local meteorological conditions.

FACILITY

The seawater for the experiments described in this report was pumped from a depth of 1.5 m below mean low water from the dock of the Duke Laboratory. The pump (Hydro-o-matic Model S4MRC300M3-6) was a three horse-power, cast iron, submersible, recessed impeller, sewage handling pump selected to minimize damage to planktonic organisms (low pressure, low rpm, and low shearing characteristics). The pump operated continuously and fed water into one of a duplicate set of 3-in. (7.6-cm) PVC supply lines. The lines were changed every two to four weeks and fresh water fed into the line not in use to kill fouling organisms that had settled inside the pipe. Seawater passed through approximately 100 m of 3-in. (7.6-cm) pipe before reaching the experimental facility.

The experimental facility consisted of a concrete block-on-slab, shed-roof building (approximately 6 m x 12 m). The wet laboratory (approximately 6 m x 9 m) was not heated or air conditioned. Air was circulated through the building by an exhaust fan, and inside air temperatures approximated ambient air temperatures. There were no windows and continuous (in general) low-level lighting was provided by single-bulb fluorescent light strips located along each wall approximately 2 m off the floor. A wooden, overhead platform was constructed approximately 2 m off the floor to hold 12 heater tanks positioned above 12 experimental tanks. The arrangement of these tanks is described in the following paragraphs. Seawater entering the building passed through a distribution pipe (3-in. PVC) and into four 1.5-in. (3.8-cm) PVC supply lines (only three of which were used). Four plastic faucets were installed along each supply line which fed water into heater tanks. The supply line then joined another 3-in. PVC bypass line which was also connected (by an adjustable valve) to the distribution pipe. Bypass water was then discharged into a drain and returned to the estuary. The entire distribution system was duplicated to allow periodic cleaning (every two to four weeks) of supply lines. The pump supplied 300 - 400 l of water per minute to the laboratory. Approximately 140 l per minute were used in the experiments with the remainder discharged.

Each plastic faucet in the supply line fed water into the bottom of one of 12 heater tanks (fiberglass, 120-liter capacity) through a standpipe arranged to discharge surplus water before it entered the heater tank. A gravity feed line of 1-in. (2.5-cm) PVC carried water from the heater tank into the experimental tanks (1.2 m in diameter; 0.6 m deep, of fiberglass with 2.5 cm of insulation in the sides and bottom). Each feed line had a capped end located approximately 5 cm from the bottom of each experimental tank. A 0.64-cm diameter hole was drilled through the cap at right angles to the feed line. Water entered each experimental tank through this single hole which was positioned to create a slow, spiraling circulation of water in the experimental tanks. The hole restricted the seawater flow and thus controlled the rate of flow (approximately 11 liters per minute) into each tank. A standpipe of 1.5-in. (3.8-cm) PVC located in the center of each experimental tank controlled the water level (46 cm) and maintained the volume of water in the experimental tanks at approximately 534 l. Water was then discharged through a drainpipe which led back to the estuary.

There were 12 experimental tanks (three replicates of four temperature treatments: ambient, and 2°C, 4°C, and 6°C above ambient). To maintain the experimental temperatures an electronic sensing and electrical current-proportioning system was designed and constructed by the Environmental Protection Agency's Environmental Research Laboratory in Narragansett, Rhode Island. This control system was located in an attached dry laboratory (approximately 3 m x 6 m) which was heated and air-conditioned. The electronic sensing system was designed to maintain temperatures of 2°C, 4°C, and 6°C above ambient seawater temperatures; it consisted of an ambient-temperature thermistor probe located in one of the three ambient-temperature experimental tanks coupled with similar thermistor probes located in each of the nine experimental tanks which were to receive heat treatment. The current-proportioning electronics provided power to a series of quartz glass immersion heaters (Cleveland Process Corp, 5 cm x 58 cm, 3000 watts). The quartz glass heaters (two each in 2°C and 4°C treatment, four each in 6°C (treatment) were placed in the heater tanks. This system provided excellent temperature control (± 0.1°C) as long as flow rates through the heater tanks into the experimental tanks remained constant. Experimental tank temperatures were recorded from 11 of the tanks using a YSI Model 47 scanning telethermometer. A Honeywell circular chart temperature recorder was used for

TABLE 1. MEAN (± STANDARD DEVIATION) OF BALANUS SPP. AND OTHER SPECIES ON FIVE PLATES PLACED IN EACH EXPERIMENTAL TANK ON 3 NOVEMBER 1976 AND COUNTED 5 - 20 JANUARY 1977. THERE WERE NO THERMAL ADDITIONS DURING THIS PERIOD.

	Balanus spp.		Other species	
Tank	Mean ±	S.D.	Mean ±	S.D.
1	52.4	14.1	4.2	0.8
2	66.2	18.5	4.4	1.5
3	69.6	20.1	5.4	4.5
4	71.4	38.7	5.2	3.7
5	50.4	15.4	5.8	1.9
6	53.4	13.9	2.4	1.5
7	81.4	24.9	4.8	3.4
8	67.4	29.6	3.0	2.1
9	50.8	11.1	4.0	1.2
10	84.6	11.1	4.0	2.8
11	72.4	16.7	4.0	2.9
12	67.8	57.1	4.8	1.3

monitoring the temperature in the twelfth tank (an ambient-temperature tank). The scanning thermometer was first connected to the "Rustrak" strip recorder (1977-1978) and later (1979) to a 10-in. (25-cm) "Esterline" strip chart recorder. Temperatures were recorded for 5 min each hour for each of the 11 tanks and continuously for the ambient tank with the Honeywell recorder.

EXPERIMENTAL PLATES

The influence of chronic, low-level thermal additions on the fouling communities was investigated by following larval recruitment and community development on the lower surfaces of unglazed ceramic tile plates (232 cm^2). The basic experimental design for each of the treatments in the laboratory and field was to have one set of permanent community plates for monitoring long-term community dynamics and another set of larval recruitment plates for assessing short-term recruitment. Individual plates were placed horizontally around the edge of the experimental tanks at alternate depths of approximately 5 cm and 20 cm below the water surface. The outer edge of each plate was approximately 8 cm from the side of the tank. In November 1976 seven plates were suspended in each of the 12 experimental tanks in an experiment to determine comparability of recruitment among tanks and plates. Five of the plates in each of the tanks were designated as permanent community plates that would be sampled only nondestructively through time. Two plates in each tank were designated as larval recruitment plates that would be censused every four weeks, cleaned of all organisms, and resuspended in their respective tanks. During this initial experimental period, all 12 experimental tanks were maintained at ambient temperature. During 4 - 20 January 1977 all organisms that had settled on the five permanent community plates in each tank were counted and these data were used to compare recruitment among plates and tanks. As shown in Table 1, most of the individuals recruited were barnacles. No discernible differences between tanks were evident even though recruitment data were extremely variable; for example, for barnacles in Tanks 9 and 10 the standard deviation was ± 11.1 while in Tank 12 it was ± 57.1.

On 21 January 1977 the temperature treatments began. The experimental tanks were located in three rows of four tanks each. Each row had one tank set at ambient, and one each at 2°C, 4°C, and 6°C above ambient. During periods when a tank was being cleaned or when equipment malfunction caused a failure in temperature control, experimental plates in the affected tank were transferred to another tank of appropriate temperature.

A thermistor failure in June and July 1977 caused water temperature to rise 20°C above ambient temperature in Tanks 6 (a 2°C tank) and 8 (a 6°C tank). This heating in midsummer resulted in complete mortality of the communities in these tanks. Because of the loss of all communities in Tanks 6 and 8, a random selection was made of three of the five permanent plates from each unaffected tank. These three plates remained in their respective tanks, while the extra plates (three each from tanks of the appropriate temperature treatments) were redistributed to Tanks 6 and 8. Thus there were three permanent plates in each tank; they were labeled Series "A." On 3 September 1977 three new plates were placed in each of the 12 tanks and these were labeled

Series "B." At the same time three permanent plates were submerged below the Duke Laboratory dock within 10 m (horizontally) of the seawater pump intake. The data from these plates are presented as the "field" series.

In February 1977 four larval recruitment plates were suspended under the Duke Laboratory dock 0.3 m below low tide within 20 m of the seawater pump intake. These were labeled "field" recruitment plates and were censused along with the 24 laboratory larval recruitment plates.

RECRUITMENT SAMPLING

Censusing of recruitment plates was done in the following manner. Plates were brought to the dry laboratory where a grid (15 x 15 cm with 1-cm squares) was positioned over them. Using a dissecting microcope mounted on a rolling platform, the technician counted all identifiable individuals within the 225-cm^2 area framed by the grid. Data are reported as counts per plate and are not normalized to a unit area by dividing by 225 cm^2. If more than 100 individuals of any one species were counted on the first 15 squares, the total counts were estimated by counting individuals in nine of the squares spaced evenly over the plate and converting these counts to estimates for the entire plate (225 cm^2). If more than 100 individuals of any one species were counted in the first 45 squares, counting was stopped and an estimate of the total number per plate made by multiplying the count by five. All recruitment plate censusing was done within a one-week period for each sampling period. During the summer field recruitment plates were sampled approximately every two weeks because of heavy settlement of fouling organisms; these data were summed over two consecutive periods to provide a recruitment value comparable to the four-week time period for the laboratory plates. Summaries of the average number of recruits for each species for any one treatment were compiled for 35 sequential time periods by averaging the number of recruits per plate and averaging the consecutive dates on which the plates were sampled for that period. This averaging permitted a period-by-period comparison of recruitment under the several treatment conditions.

The recruitment sampling technique had the limitation that some individuals were not large enough to count, either because they had just settled or because they grew very slowly. Also, this technique did not account for individuals which might have settled during the 24-hour period when the plates were being cleaned and soaked in fresh water prior to resubmergence.

PERMANENT COMMUNITY SAMPLING

Permanent community plates were nondestructively sampled for percent cover by each species. Plates were removed from the field or experimental tanks and placed in a small aquarium filled with running seawater from the appropriate temperature treatment. Percent cover was estimated by a point sampling technique using a plot of 100 random points which had been generated by computer on a 15 cm x 15 cm area. (A different set of random points was generated for each successive sampling.) These points were traced onto a glass plate which was positioned above the plate to be counted. A record was kept of the species observed under each point using a siting device to reduce parallax. In cases were the point fell on a species attached to another living species, both were counted; thus there were occasions when greater than 100 percent cover was recorded for a given plate. Canopies of colonial species were not counted; only the base area of attachment was counted. Motile species which were observed were not counted, but were removed from the plates.

Because sampling all the permanent plates required approximately three weeks, there could occur significant changes in percent cover that depended on time and not necessarily on treatment. This made comparison among treatments difficult; therefore the percent cover for each plate was estimated in the following manner. A consecutive date (Table 2) was chosen which fell between the end of one sampling period and the start of another. The following equation was used to create a set of data estimating the percent cover for each species for that specific consecutive date:

$$P_e = [(P_2 - P_1/D_2 - D_1)((D_3 - D_1) + P_1)]$$

where:

P_e = percent cover on chosen day (D_3)
P_1 = percent cover on initial day (D_1)
P_2 = percent cover on final day (D_2)

With all the percent cover data estimated for a single consecutive day it was then possible to compare treatments. Percent cover data are not normally distributed and, therefore, an arcsine transformation was applied to the data before calculating means and standard deviations.

Data analysis and figure preparation were done using a PDP 11/34 computer system.

ANCILLARY STUDIES

During the course of the project three ancillary studies were undertaken to describe the influence of communities on the concentration of phytoplankton suspended in the seawater as it flowed through the experimental system. These studies included: (1) determination of flow rates of water through the system, (2) estimation of phytoplankton biomass within the system, and (3) estimation of clearance rates of communities. Since most of the species in the community were suspension feeders, it is possible to extrapolate the results of these studies to effects on other particulate matter, particularly zooplankton, in discussing the influence of feeding activities by the communities on their own growth and larval recruitment. The three investigations involved measurements of flow rates, chlorophyll _a_ concentrations, and community clearance rates.

Flow rates were estimated by measuring the volume of water flowing from the discharge pipe from each experimental tank. Replicate measurements

TABLE 2. LIST OF CONSECUTIVE DATES CHOSEN FOR TEMPORAL ADMUSTMENT OF PERCENT COVER DATA FROM PERMANENT PLATES SO THAT COMPARISONS COULD BE MADE BETWEEN TREATMENTS

1977		1978		1979	
Cons. Day	Date	Cons. Day	Date	Cons. Day	Date
145	May 25	389	January 24	735	January 5
170	June 19	436	March 12	765	February 4
202	July 21	470	April 15	792	March 3
229	August 17	505	May 20	820	March 31
260	September 17	540	June 24	850	April 30
288	October 15	575	July 29	890	June 9
320	November 16	620	September 12	925	July 14
348	December 14	670	November 1	950	August 8
		705	December 6	980	September 7
				1005	October 2
				1035	November 1

indicated that the expected precision of this technique was ± 2 percent of the measured flow.

To estimate phytoplankton biomass, chlorophyll a concentrations in seawater samples were analyzed fluorometrically (Turner Model 111) using the technique of Strickland and Parsons (1972). The only modification of this technique was that the glass fiber filters used to collect phytoplankton were folded, wrapped in aluminum foil, labeled, and stored frozen until analyses were completed. Two types of chlorophyll a studies were performed in 1978 and 1979. The first set was conducted over 12-hour periods, with chlorophyll a samples collected hourly at the pump intake (dock), in each of a series of four heater tanks, and in their respective experimental tanks (ambient, 2°C, 4°C, and 6°C). This sampling was conducted six times between February 1978 and November 1979. In the second set of chlorophyll a studies, weekly samples were taken synoptically (within a 30-min period) from the pump intake (dock) and each of the 12 experimental tanks. These samples were taken between January and December 1979.

Clearance rates were measured in a cylindrical (30.5 cm x 48 cm) fiberglass container open at the top and sealed at the bottom. This container was placed near the center of the appropriate laboratory experimental tank and filled by pump with filtered (5-micron filter) seawater from that tank. Water surrounding the cylinder served to control water temperature within the cylindrical container. Clearance rates of communities on field plates were measured similarly within an ambient temperature tank in the laboratory. A volume of 1 - 8 liters (depending upon the experiment) of mixed phytoplankton (described below) was then added to each cylinder. A small "Little Giant" submersible pump was placed on the bottom of the cylinder, and water from this pump circulated continuously through the Turner Model 111 recording fluorometer and back to the top of the cylinder. The pump and an air stone placed in each cylinder rapidly mixed and aerated the water. A 10-in. (25-cm) recorder continuously recorded the *in vivo* fluorescence of water pumped through the fluorometer. After the system had been operated for several minutes the community plate to be studied was placed in the cylinder and the experiment was begun. The volume of water in the system was approximately 35 liters. No allowance was made in the calculations for the slight difference in volume caused by differences in the size of the communities on the plates. In general, clearance experiments lasted from 15 - 60 min. During the initial 5 - 10 min, clearance rates of the communities increased as the suspension feeders became active following plate handling. Clearance rates subsequently became more or less constant and remained so until most of the phytoplankton had been removed, at which point there was no further decrease in fluorescence.

A 500-ml sample of water was taken from the tank at the start of each experiment and filtered through a glass fiber filter (approximately 1 micron) to determine background, particle-free, *in vivo* fluorescence. At the end of each feeding experiment this particle-free water was slowly poured through the flow cell of the fluorometer and the value was recorded. Clearance rate is based upon changes in the fluorescence reading during the 10- to 20-min logarithmic decrease in fluorescence. The readings "before" and "after" this period were 5 - 15 fluorescence units above those at which the communities typically ceased clearing the water. Clearance rates were calculated using the formula:

$$CR = V\ (\log C_o - \log C_t)\ /\ (t)\ (\log_e)$$

where:

CR = clearance rate (liters per hour)
V = volume of container (35 liter)
C_o = initial corrected fluorometer reading
C_t = final corrected fluorometer reading
t = time (hours).

Prior experiments had shown an excellent linear relationship ($R = 0.99$) between *in vivo* fluorescence and extracted chlorophyll *a* values. Therefore *in vivo* fluorescence readings were used directly in the calculation of clearance rates after being corrected for background fluorescence.

Phytoplankton used for estimating clearance rate were cultured in continuous, strong illumination in 20-liter glass jars. Unfiltered seawater from the seawater system was placed in the jars and enriched with nitrate, phosphate, and silicate (F/5 of Guillard and Ryther 1962). These jars were stirred with an air stone and the cultures of naturally occurring phytoplankton were allowed to develop for two to four days before being used. At the end of this time these cultures consisted of mixtures of naturally occurring phytoplankton dominated by diatoms which responded most rapidly to enriched conditions.

Several different clearance rate studies were performed. In the first study clearance rates of all 72 community plates from the experimental tanks and the three field communities were determined individually during August and December 1979. Data for a given treatment were averaged to give a mean clearance rate per plate for field, ambient, 2°C, 4°C, and 6°C treatments. Routine monthly sampling data for the permanent plates for August and November 1979 provided information on average percent cover, average number of species per plate, and average percent cover by different taxonomic groups. At the December sampling period, total wet weight of the biotic assemblage, including shells attached to each plate, was determined. Very few organisms other than oysters were present on the 6°C plates and many of these were dead. The wet weights of the 6°C plates were corrected for dead oysters by estimating the percent dead to the nearest 25 percent and subtracting this from the wet weight. Hence the weights for the living organisms on the 6°C plates are very rough estimates. All clearance rate data for the December period were divided by the wet weights to give weight specific estimates. These rates were averaged for each treatment. Due to the nonparametric variability in clearance rates among plates in any one treatment, the significance of the difference between treatments was determined using a Wilcox-Man-Whitney rank sum test (Snedecor and Cochran 1967).

A second study was conducted during the summer (June - August 1979) to provide data on diurnal variations in the clearance for the ambient laboratory plates. Clearance rates were measured once every four hours in a series of six replicate experiments. For each time period, four sequential 10- to 20-min experiments were averaged. Two of these experiments lasted for one day, one for two days, one for four days, and two for five days.

In a third study the influence of the concentration of phytoplankton on clearance rates was examined. The clearance rate of an ambient temperature community was measured. The experiment was repeated three times during the summer of 1979, with four sequential experimental runs (10 - 20 min each) performed on each of three consecutive days. A different concentration of phytoplankton was used each day to investigate the influence of concentration on clearance rates.

OPERATIONAL HISTORY OF THE SYSTEM

Except for brief interruptions, seawater flowed continuously from November 1976 to December 1979 through all the experimental tanks. Brief interruptions were due to (1) clogging of the faucets supplying water to individual tanks, (2) changing seawater lines, or (3) power failures during which the seawater pump stopped. There was never any indication that these flow failures caused mortality of any organisms in the communities.

Seawater flow into each of the heater tanks was usually checked and adjusted twice daily on work days and once daily on weekends and holidays. Frequently these inflows were partially clogged by silt and small organisms which caused some variability in the flow rates through the experimental tanks. Occasionally complete clogging of lines caused the temperature to decrease in the heated experimental tanks. Periodic measurements of flow rates through the experimental tanks were made and these are reported in the results of ancillary experiments.

During the course of the experiment it was necessary periodically to clean the heater tanks, pipes and experimental tanks of accumulated silt and fouling organisms. Heater tanks and pipes leading into experimental tanks were cleaned once a month during 1976 and 1977, quarterly during 1978, and once every three weeks during 1979. Initially experimental tanks were cleaned in August 1977, March 1978, and September 1978; during 1979 they were cleaned once every three weeks.

The record of ambient temperatures taken from the Honeywell recorder (Tank 10) was summarized as daily maximum and minimum temperatures and these were plotted for 1977-1979 (Figure 1). Because the seawater took less than one minute to flow through the pipe from the pump to the laboratory the temperature of water flowing into the ambient laboratory tanks was ± 0.5°C of field water temperatures. Even though the volume of water in the ambient tanks buffered rapid changes in inflow temperatures, the changes which occurred over a tidal cycle were clearly evident.

In 1977 a minimum temperature of approximately 1°C was recorded on the day that the temperature additions to the tanks began (January 21). A maximum of approximately 31°C occurred in mid-July 1977; the average maximum

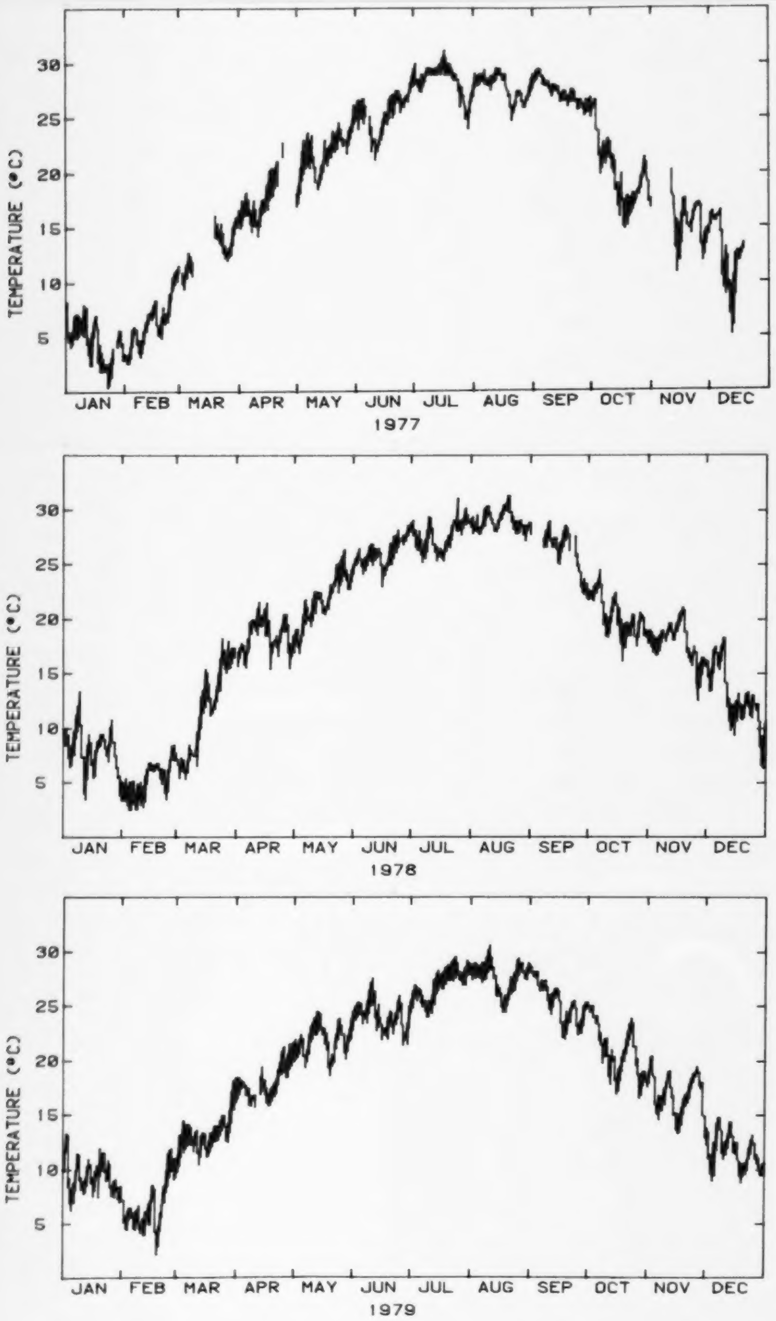

Figure 1. Record of ambient seawater temperatures plotted as daily maximum and minimum values. Blank spaces indicate recorder failures.

temperature, however, was approximately 29°C. In 1978 a minimum temperature of approximately 2°C occurred in early February. At this time the ambient temperature oscillated between 2°C and 5°C for approximately 10 days. A summer maximum of approximately 31°C occurred for several days in mid-August 1978. In 1979 a minimum temperature of approximately 2°C occurred on one day in mid-February; however, the minimum temperature generally ranged from 4°C - 6°C for the first two weeks of February. A maximum temperature of approximately 31°C occurred on one day in mid-August 1979; however, the maximum temperature generally ranged between 27°C and 29°C during the latter part of July and the first part of August.

Figure 1 shows that the normal daily temperature range is approximately 2°C with more extreme daily ranges occurring in the spring and autumn as major weather fronts move through with their rapid changes in air temperatures. In the winter the daily minimum temperatures are most often associated with low tides at night as water from the shallow bay system loses heat to the colder atmosphere. In the summer minimum temperatures are associated with high tides which bring cooler coastal waters into the bay. Maximum water temperatures in the winter are associated with high tides which bring warmer coastal waters into the bay while maximum temperatures in the summer are associated with low tides during the day.

The periodicity of major weather changes (every one to two weeks) is reflected by the saw-toothed nature of the curves in Figure 1. These weather fronts can result in changes in water temperatures (increases or decreases) of as much as 10°C in a period of a few days. Such large changes are particularly evident in the spring and autumn. The daily and weekly ranges between maximum and minimum temperatures were less in midwinter and midsummer.

There were significant differences among the annual temperature cycles for the years 1977, 1978, and 1979. January and February 1977 were much colder than these months in 1978, and in 1978 they were somewhat colder than in 1979. Maximum temperatures in 1977 occurred in July as compared to August maxima in 1978 and 1979.

During the experiment (except as noted in Table 3) the temperatures in the experimental tanks receiving thermal additions cycled at their appropriate temperatures with no noticeable time lag when compared to the ambient temperature tanks. Thus the variability both daily and seasonally was the same in the tanks with thermal additions as that in the ambient temperature tanks.

The temperature history and placement of the permanent plates in each tank was complex. Table 3 summarizes information drawn from the log books of daily activities and the temperature records. The temperature control system (particularly the thermistors and heaters) experienced frequent failures which affected one or more of the experimental tanks. In addition, the sensitivity of the temperature control system to moderate changes in flow rates caused by partial clogging of the system resulted in deviations from the desired temperature. A major malfunction of the temperature control system occurred during the summer of 1977 when the control thermistor in an ambient tank

TABLE 3. CHRONOLOGICAL SUMMARY OF THE TEMPERATURE HISTORY AND PLACEMENT OF THE PERMANENT PLATES

On 30 November 1976 seven plates were placed in each of the twelve experimental tanks. Ambient temperature seawater flowed through all of the tanks until 1 January 1977 when temperature differentials were established. Tanks were numbered one through twelve in three rows of four tanks each. Each row had one tank at each of the experimental temperatures. These treatments were as follows:

Row 1: Tank 1, 2°C; Tank 2, 4°C; Tank 3, 6°C; Tank 4, ambient;
Row 2: Tank 5, 4°C; Tank 6, 2°C; Tank 7, ambient; Tank 8, 6°C;
Row 3: Tank 9, 6°C; Tank 10, ambient; Tank 11, 4°C; Tank 12, 2°C.

Plates were moved from one tank to another with the same treatment when tanks were being cleaned and when temperature control was lost.

1/21/77	Experimental temperatures established.
1/25/77	Plates in Tanks 2, 11 and 12 exposed 18 hrs to ambient temperature.
1/26/77	Plates in all 12 tanks exposed 7 hrs to ambient temperature except those in Tank 2 which were exposed to ambient temperature for 50 hrs.
2/20/77	Tank 2 plates moved to Tanks 5 and 11; replaced 2/28/77.
2/25/77	Tank 1 plates exposed 96 hrs to ambient temperature before being moved to Tanks 6 and 12 on 3/2/77. Returned 3/3/77. Tank 12 plates moved to Tanks 1 and 6 after 12 hrs exposure to ambient temperature; replaced 3/2/77.
3/1/77	Tank 11 plates moved to Tanks 2 and 5 after 6 hrs exposure to ambient temperature; replaced 3/3/77.
3/17/77	Plates in Tank 2 exposed to temperature of 5°C above ambient for an unknown period (less than 24 hrs). Tank 2 plates moved to Tanks 5 and 11. Replaced 3/31/77.
3/27/77	Plates in Tank 6 exposed 12 hrs to ambient temperature moved to Tanks 1 and 12. Replaced 4/1/77.
4/3/77	For an unknown period of up to 36 hrs the plates were exposed to temperatures above ambient as follows: Tank 2 at 7°C, Tank 3 at 13°C, Tank 11 at 7°C and Tank 12 at 3.5°C. The system was turned off and all tanks were at ambient temperature for 30 hrs except Tank 3 which was off for 72 hrs.

(continued)

TABLE 3 (continued)

5/9/77	Entire system in error for 3 days with all tanks at 1°C - 2°C above set point except Tank 8, which was 2°C - 3°C above the set point.
5/11/77	Temperature in Tank 9 was 1.5°C below set point for 48 hrs.
5/15/77	All tanks at ambient temperature for 32 hrs.
5/23/77	Tank 5 plates moved to Tanks 2 and 11; Tank 6 plates moved to Tanks 1 and 12. Both sets of plates returned 5/26/77.
6/6/77	System failure; all tanks exposed to elevated temperatures above set points. Plates in tanks indicated exposed to the following peak temperatures above ambient: 1, 6°C; 2, 6°C; 3, 11°C; 5, 6°C; 6, 6°C; 8, 19°C; 9, 15°C; 11, 7°C; 12, 6°C. Communities on plates in Tank 8 were dead. Tank 9 plates moved to Tanks 3 and 8.
6/7/77	System turned off for 27 days (until 7/14/77).
7/18/77	Tank 6 plates exposed to peak temperature of 14°C above ambient during a cycle lasting 7 hrs.
7/25/77	Tank 6 plates exposed to temperature of 20°C above ambient for a period of 24 hrs. Communities on all plates in Tank 6 were dead.
7/26/77	Random selection of 3 of the 5 permanent plates from each tank to remain in that tank except for Tanks 6 and 8. Three of the plates to be removed from Tanks 1 and 12 selected to go into Tank 6 and three plates from Tanks 3 and 9 selected to go into Tank 8 to replace communities killed in those tanks by elevated temperatures. These plates were labeled Series" A."
8/3/77	Three new permanent plates placed in each tank and labeled Series "B."
8/11/77	Tank 6 plates exposed to temperature 1°C above set point for 17 days.
8/19/77	Tank 3 plates exposed to temperature of 4°C above set point for 3 hrs.
8/28/77	Tank 6 plates exposed to temperature of 5°C above set point for 2 hrs.
8/31/77	Temperature in Tank 6 cycling 1°C - 5°C above set point for 2 days.
9/2/77	Tank 6 plates moved to Tank 12. Returned 9/16/77.

(continued)

TABLE 3 (continued)

9/8/77	Tank 3 plates exposed to temperature of 15°C above ambient for 4 - 6 hrs. Tank 3 plates moved to Tanks 8 and 9. Returned 9/16/77. Tank 1 plates exposed to temperature 6.5°C above ambient for 1 - 2 hrs, then to ambient temperatures for 5 days.
9/13/77	Tank 1 plates moved to Tank 6. Returned 9/16/77.
9/15/77	Tank 2 plates exposed to temperature of 7.5°C above ambient for 1 - 4 hrs, heater turned off, and then plates were exposed to ambient temperature for 24 hrs.
10/7/77	Tank 6 plates at ambient temperature for 72 hrs.
10/31/77	Tank 2 plates moved to Tanks 5 and 11. Returned 11/2/77.
11/4/77	Tank 6 plates exposed to temperature 5.1°C above ambient during the night.
11/5/77	Tank 9 plates exposed to ambient temperature for 72 hrs.
11/10/77	Tank 5 plates exposed to ambient temperature for 12 hrs.
11/21/77	Tank 2 plates exposed to cycling temperatures as high as 7.5°C above ambient for 24 - 48 hrs.
12/6/77	Tank 3 plates exposed to short term cycling (hours) of temperatures ranging as high as 9°C above ambient for 8 days.
12/23/77	Tank 9 plates exposed to ambient temperature for 7 days.
1/3/78	Tank 5 plates exposed to ambient temperature for 3 days.
1/17/78	Tank 5 plates exposed to temperature of 6°C above ambient for 9 hrs.
1/26/78	Tank 2 plates exposed to 9.3°C above ambient for 4 hrs. Tank 5 plates exposed to 6.3°C above ambient for 2 hrs. Tank 9 plates exposed to temperature of 10.2°C for 2 hrs and 9.8°C for 4 hrs. Tank 11 plates exposed to temperature of 11.2°C above ambient for 2 hrs. Tank 12 plates exposed to temperature of 5.3°C above ambient for 4 hrs.
2/15/78	Tank 2 plates exposed to temperature of 6.2°C above ambient.
3/10/78	Tank 6 plates exposed to air for 2 - 4 hrs.
3/14/78	Tank 12 plates exposed to air for 30 min. Tank 2 plates exposed to ambient temperature for 24 hrs.
3/17/78	Tank 1 plates exposed to ambient temperature for 12 hrs.

(continued)

TABLE 3 (continued)

3/20/78	System failure. All tanks at ambient temperature for 96 hrs.
3/25/78	Tank 2 plates moved to Tank 8. Returned 3/29/78.
3/27/78	Tank 9 plates moved to Tank 3, Tank 10 plates moved to Tank 7, Tank 11 plates moved to Tank 5, and Tank 12 plates moved to Tank 6. All plates returned to their respective tanks 3/29/78.
4/10/78	Tank 5 plates exposed to ambient temperature for 24 - 48 hrs.
4/11/78	Tank 9 plates exposed to temperature 7.4°C above ambient then to ambient for 72 hrs.
4/17/78	Tank 3 plates exposed to temperature 8.5°C above ambient.
4/24/78	Tank 12 plates exposed to ambient temperature for 24 - 48 hrs.
5/6/78	Tank 3 plates moved to Tanks 8 and 9. Returned 7/21/78.
5/15/78	YSI temperature recorder not functioning since 4/6/78.
5/19/78	Tank 5 plates moved to Tanks 2 and 11. Returned 5/24/78.
5/23/78	Tank 2 plates at ambient temperature for 12 hrs.
6/5/78	Tank 5 plates at ambient temperature for 24 to 48 hrs.
6/19/78	Tank 9 plates exposed to temperature of 1.6°C above ambient for 24 to 48 hrs.
7/20/78	Tank 5 plates exposed to temperature of 5°C above ambient for 4 hrs.
7/21/78	Tank 9 plates exposed to ambient temperature for 12 hrs.
7/23/78	Tank 8 plates exposed to temperature of 8.8°C above ambient (approximately 37°C) for 12 to 24 hrs. Tank 8 plates moved to Tank 3. Returned 7/25/78.
8/1/78	Tank 12 plates exposed to air for some time (less than 6 hrs).
8/2/78	Tanks 3, 8 and 9 plates exposed to ambient temperature for 24 hrs.
8/18/78	Tank 8 plates exposed to temperature 11.2°C above ambient (approximately) 39°C for 12 hrs.
8/23/78	Tank 8 plates moved to Tank 3. Replaced 9/24/78.
8/26/78	Tank 11 plates exposed to ambient for unknown time.

(continued)

TABLE 3 (continued)

8/28/78	Tank 3 plates exposed to temperature of 7.9°C above ambient (approximately 31°C) for 1 hr.
9/20/78	Tank 3 plates exposed to temperature of 8.5°C above ambient for 4 hrs. Tank 1 plates exposed to temperature of 4.4°C above ambient for 4 hrs. Tank 3 and 1 plates exposed to ambient temperature for 18 hrs.
9/25/78	All plates exposed to ambient temperature for 8 hrs.
10/24/78	Tank 3 plates exposed to ambient temperatures for 24 hrs.
11/23/78	Tank 11 plates, exposed to ambient temperature for 4 hrs, moved to Tanks 5 and 2. Returned 11/24/78.
1/22/79	Tank 9 plates moved to Tanks 3 and 8. Returned 1/23/79.
2/1/79	Tank 3 plates exposed to air for 10 - 20 min.
2/3/79	Tank 3 plates moved to Tanks 8 and 9. Returned 2/12/79. Exposed to ambient temperature for 5 hrs before moving.
2/5/79	All plates exposed to ambient temperatures for 3.5 hrs.
2/17/79	Tank 8 plates moved to Tanks 3 and 9. Returned 2/19/79.
3/27/79	Tank 8 plates moved to Tanks 3 and 9. Returned 4/9/79.
4/24/79	Tank 8 plates exposed to temperature of 8°C above ambient (± 1 hr). Tank 8 plates moved to Tanks 3 and 9. Returned 8/17/79.
5/3/79	Tank 9 plates exposed to ambient temperature for 24 hrs.
5/23/79	Tank 6 plates moved to Tanks 1 and 12. Returned 8/16/79.
6/11/79	Tank 9 plates at ambient temperature for 24 hrs.
6/19/79	Tank 2 plates exposed to temperature of 6.1°C above ambient (± 2 hrs). Tank 2 plates moved to Tanks 5 and 11. Returned 6/21/79.
6/24/79	Tank 2 plates exposed to temperature of 7.6°C above ambient (± 4 hrs). Tank 2 plates moved to Tanks 5 and 11. Returned 6/27/79.
7/12/79	Tank 2 plates exposed to temperature of 5.7°C above ambient (± 1 hr). Tank 2 plates moved to Tanks 5 and 11. Returned 8/16/79.
7/23/79	Tank 5 plates exposed to ambient temperature for 15 hrs.
7/26/79	All plates exposed to ambient temperature for 15 hrs.

(continued)

TABLE 3 (continued)

8/20/79	Tank 2 plates moved to Tanks 5 and 11. Returned 8/24/79.
11/4/79	Tank 3 plates moved to Tanks 8 and 9. Returned 11/14/79.
11/16/79	Tank 3 plates exposed to temperature of 8.2°C above ambient (± 1 hr).
11/17/79	Tank 2 plates moved to Tanks 5 and 11. Replaced 11/26/79.
11/20/79	Tank 3 plates exposed to temperature of 9.3°C above ambient (± 3 hrs). Tank 1 plates exposed to temperature of 4.9°C above ambient.
11/21/79	Tank 3 plates exposed to temperature of 12°C above ambient (± 1 hr).
11/29/79	Tank 2 plates exposed to temperature of 6.5°C above ambient for a few minutes.
12/19/79	Experiment ended.

failed and communities in all heated tanks were exposed to peak temperatures from 6°C to 20°C above the ambient water temperature. As a result communities in Tanks 6 (2°C) and 8 (6°C) were killed. Due to the death of all communities in these two tanks, plates from the other tanks were redistributed so that each experimental tank contained three of the original plates which were designated Series "A"; three new plates were also added to each tank and designated Series "B." The Series "A" communities in Tanks 6 and 8 were drawn from those extra plates removed from the tanks having the same temperature treatment. Other less extreme temperature variations occurred frequently. To estimate the importance of these variations to experimental plates the hourly temperature records (5 min/hr) have been summarized (approximately 8208 hr between 2 January and 9 December 1979) for each tank (Table 4). These data include times when plates were moved from their tank to another at the same temperature and thus represent temperature history but not placement history of the plates. Placement history is given in Table 3.

Data in Table 4 indicate that from 83 - 98 percent of the time the temperature experienced by the communities was ± 0.2°C of that desired while 99 percent of the time it was ± 1.0°C. Thus although temperature excursions from the desired level were frequent, the total amount of time during which the plates were exposed to temperatures greater than ± 1.0°C of those desired was approximately 82 hr of a total of 8208 hr. One reason for these high percentages was the practice of moving plates from one tank to another of the desired temperature when cleaning tanks or when there was a failure of the temperature control for a tank.

TABLE 4. PERCENTAGE OF TIME (% TIME) THE PLATES FROM EACH HEATED EXPERIMENTAL TANK SPENT AT THE DESIRED TEMPERATURE (2 JANUARY - 9 DECEMBER 1979)

Plates from Tank Number	Desired Temperature Differential (°C)	Number of Readings	% Time ±0.2°C	% Time ±1.0°C
1	2	8138	96.8	99.3
2	4	8155	92.9	98.7
3	6	8145	87.3	98.9
5	4	8110	90.7	98.9
6	2	8155	83.3	99.5
8	6	8155	93.3	98.9
9	6	8144	89.9	98.5
11	4	8107	86.3	99.4
12	2	8141	98.0	99.7

SECTION 5

RESULTS

LARVAL RECRUITMENT

Summary

Recruitment studies were designed to document the species pool available to the permanent plate fouling communities and to observe the influence of the experimental system and temperature on recruitment of fouling community species. The laboratory system alone (with no thermal additions) strongly influenced the numbers of individuals of most species recruited, the structure of the community recruited, and the number of species recruited in comparison with the field situation. Temperature increases within the laboratory system resulted in significant changes (species specific) in the numbers of individuals of most of the species recruited. Temperature increases also resulted in an increase in the annual minimum of species recruited per plate and a decrease in the annual maximum. The number of species recruited in the 4°C and 6°C treatments took on a semiannual pattern that differed from the annual pattern of 0°C and 2°C treatments and the field. In addition, higher temperatures (particularly 4°C and 6°C) resulted in earlier settlement in the spring for several species. The effects of temperature on the structure of the recruiting communities were not predictable, probably as a combined result of (1) the shift in timing of recruitment for some, but not all, species and (2) the positive, negative, or neutral changes in numbers recruited depending upon species or time of year or both.

General Results

During the three years of the experiment 30 species (Table 5) were encountered. Two species could not be identified: (1) an unknown anemone which occurred rarely and never grew large enough to be identified, and (2) a tunicate which frequently occurred in large numbers but was too small to be identified. Of the 30 species encountered, only 21 occurred with a mean of 10 or more individuals per plate in any one treatment at any one time (mean of six plates per treatment in the laboratory and four plates in the field); these 21 species are discussed in the following paragraphs. The nine species that did not fulfill the requirement of a mean of 10 or more individuals per plate for one or more time periods are indicated by * in Table 5; they are not discussed below.

Recruitment data in this study have been analyzed in two ways. In one analysis, each separate species is described as to when it appeared and

TABLE 5. SPECIES IDENTIFIED AS RECRUITS ON LARVAL PLATES IN THE FIELD AND/OR IN THE LABORATORY TANKS

Phylum Porifera
*1. _Halichondria bowerbanki_
2. _Leucosolenia canariensis_
3. _Leucosolenia_ sp.

Phylum Coelenterata
Class Hydrozoa
4. _Eudendrium ramosum_
*5. _Pennaria tiarella_
6. _Tubularia crocea_

Class Anthozoa
*7. _Astrangia danae_
*8. _Diadumene leucolena_
*9. Unknown anemone

Phylum Bryozoa
*10. _Anguinella palmata_
11. _Bugula avicularia_
12. _Bugula neritina_
13. _Electra monostachys_
*14. _Membranipora tenuis_
15. _Schizoporella errata_

Phylum Annelida
Class Polychaeta
16. _Hydroides dianthus_
17. _Sabellaria vulgaris_
18. _Spirorbis borealis_

Phylum Mollusca
Class Pelecypoda
*19. _Anomia simplex_
20. _Argopecten irradians_
21. _Crassostrea virginica_
*22. _Geukensia demissa_

Phylum Arthropoda
Subclass Cirripedia
23. _Balanus_ spp.

Order Amphipoda
24. _Corophium acherusicum_

Phylum Urochordata
25. _Ascidia interrupta_
26. _Botryllus schlosseri_
27. _Molgula manhattensis_
28. _Perophora viridis_
29. _Styela plicata_
30. Unknown tunicate

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* Species which were never recruited in significant numbers (mean of 10 or more per plate for one or more time periods)

disappeared, which indicates seasonal and annual variations, and as to how its appearance was influenced by experimental treatment. Counts for each species on all plates from all the treatments were compared (Table 6) for each sampling period using a Wilcoxon Rank-Sum test (Snedecor and Cochran, 1967) for significance in differences between the different treatments. Table 6 is a summary of significant differences ($p = 0.05$) among treatments in the recruitment of individual species and of the community as a whole (totals and percent of total which are different). The table gives the number of times there was a significant difference between two treatments (D_F) and the total number of times there was significant recruitment (T_o). For instance, in comparing recruitment of *Tubularia crocea* in the field with that at 0°C, there were six time periods with significant recruitment in one or both treatments and for five of the six times recruitment was significantly different between the two. Differences in recruitment could be both positive and negative depending upon the species, the time period, and the treatment. There were a total of 35 possible time periods; however, comparisons were not made when both treatments had a mean recruitment of < 10 individuals per plate or when plates were missing from a treatment due to temperature failures in the system.

For the second method of analysis of recruitment data, community structure of the recruits for each plate and time period was assessed using a cluster analysis technique (weighted pair group linkage, Sokal and Sneath 1963) based upon the similarity (Morisita 1959) among the communities.

Individual Species

Two species of sponges were recruited in significant numbers on at least one plate at one time during the three-year period. *Leucosolenia canariensis* and *Leucosolenia* sp. (Table 7) occurred so infrequently that no pattern of recruitment was discernible.

Two species of hydrozoans were recruited. *Eudendrium ramosum* recruited best during the summer period (May - October) and significant recruitment was restricted to the field plates. There was slight recruitment in the laboratory, but never with an average of 10 or more per plate for any period. *Tubularia crocea* (Table 7) was recruited on plates in the spring (March - June). There was significantly greater recruitment on the field plates than on any of the laboratory plates five of the six times (Table 6). In March 1977 there was significantly greater recruitment on the 6°C plates than on the 0°C, 2°C, or 4°C plates, suggesting that warmer water had promoted earlier settlement of *T. crocea* ; however, this was not observed in subsequent years.

No species of anthozoans were observed to recruit with an average of 10 or more per plate for any one time period during the experiment.

Four bryozoan species were recruited in significant numbers during the experiment, and three of these occurred frequently and in large numbers. *Schizoporella errata* (Figure 2), an encrusting bryozoan, settled in large numbers during the warm months of the year, particularly in the late spring and autumn. In 1977 and 1978 recruitment in the field was approximately two

TABLE 6. COMPARISON OF SPECIES RECRUITMENT ON LARVAL PLATES AS A FUNCTION OF TREATMENT. RANK SUMS ANALYSIS WAS USED TO COMPARE RECRUITMENT ON PLATES IN ONE TREATMENT WITH THOSE FROM ANOTHER TREATMENT. THE TABLE GIVES THE TOTAL (To) NUMBER OF TIMES THERE WAS A SIGNIFICANT (AVERAGE OF 10 OR MORE PER PLATE) RECRUITMENT IN EITHER OF THE TWO TREATMENTS AND THE NUMBER OF THAT TOTAL (Df) WHICH WERE SIGNIFICANTLY DIFFERENT ($p = 0.05$). FIELD TREATMENTS (F) HAD FOUR PLATES FOR EACH COMPARISON WHILE LABORATORY TREATMENTS (0°C, 2°C, 4°C, AND 6°C) HAD SIX PLATES FOR EACH COMPARISON.

SPECIES	F-0°C		F-2°C		F-4°C		F-6°C		0°C-2°C		0°C-4°C		0°C-6°C		2°C-4°C		2°C-6°C		4°C-6°C	
	Df	To	Df	To	Df	To	Df	To	Df	To	Df	To	Df	To	Df	To	Df	To	Df	To
Leucosolenia canariensis					0	1					1	2								
Leucosolenia sp.	1	2			1	2					0	2								
Eudendrium ramosum	6	8	5	7	6	8	3	5												
Tubularia crocea	5	6	5	6	5	6	5	6					1	1			1	1	1	1
Bugula avicularia	15	22	12	20	18	24	13	20	6	21	15	25	14	21	10	20	12	21	3	18
Bugula neritina	15	18	15	17	18	21	15	19	5	10	7	14	6	11	7	12	6	11	5	12
Electra monostachys	2	3	2	2	1	2	1	2	0	1	0	1	0	1						
Schizoporella errata	15	21	17	18	20	21	16	18	5	6	6	7	7	8	3	3	5	5	1	3
Hydroides dianthus	21	21	19	19	21	23	16	17	2	3	2	5	3	4	0	4	3	5	4	5
Sabellaria vulgaris	14	14	10	10	13	14	10	10					1	1			1	1	1	1
Spirorbis borealis	17	26	22	25	32	32	22	27	18	24	27	30	17	25	21	27	19	26	18	26
Argopecten irradians	1	1	1	1	1	1	1	1												
Crassostrea virginica	13	19	14	15	14	18	11	14	3	11	3	14	5	13	1	9	3	12	2	12
Balanus spp.	33	33	30	30	33	33	28	28	8	12	7	13	3	13	1	7	5	11	6	11
Corophium acherusicum	14	27	18	24	18	28	18	23	4	22	8	25	17	23	3	23	12	23	11	21
Ascidia interrupta	7	10	5	9	8	10	7	9	0	1					0	1	0	1		
Botryllus schlosseri	3	6	2	5	2	4	3	3	0	5	4	7	4	5	1	6	1	5	0	2
Molgula manhattensis	1	2	1	3	1	2	0	1	0	2	0	1			0	2	0	2	0	1
Perophora viridis	1	5	0	2	1	2			0	2	1	4	1	3	0	3	0	2	0	1
Styela plicata	15	16	13	13	15	16	11	11												
Unknown tunicate	7	10	4	8	7	12	6	9	1	8	2	10	6	10	1	8	6	8	2	10
TOTALS	206	270	195	234	195	280	186	223	52	128	83	159	85	138	48	125	74	134	54	124
Percent of the total which are different	76%		83%		70%		83%		40%		52%		62%		38%		55%		44%	

TABLE 7. AVERAGE NUMBER OF RECRUITS PER PLATE FOR TIME PERIODS WHEN SIGNIFICANT (> 10/plate) RECRUITMENT TOOK PLACE IN ONE OR MORE TREATMENTS. THIS TABLE PRESENTS RECRUITMENT DATA FOR THOSE SPECIES WHICH ARE NOT GIVEN IN FIGURES.

			Treatment			
Species	Date	Field	0°C	2°C	4°C	6°C
Leucosolenia canariensis	7/79				22.2	
Leucosolenia sp.	6/79		65.3		37.7	
	7/79		18.7		39.3	
Eudendrium ramosum	6/77	12.5				
	6/78	90.5				
	7/78	38.8				
	8/78	14.5				
	9/78	11.8				
	10/78	11.8				
	5/79	29.5				
	8/79	13.3				
Tubularia crocea	3/77		0.2			18.8
	4/77	22.0	0.7	0.5	0.7	
	5/77	42.3				
	5/78	26.8	0.5	0.3		
	4/79	42.8	2.3	0.3	0.8	
	5/79	70.0				
	6/79	16.8	0.2			
Electra monostachys	5/78		22.2		0.2	
	2/79	18.5	0.8	1.7	3.8	4.3
	4/79	60.8				
Sabellaria vulgaris	6/77	17.5	0.2			0.3
	7/77	10.5	0.7	0.2	1.3	
	8/77	42.0				
	8/77	10.5				
	10/77	72.0			0.2	0.5
	12/77	68.5				
	1/78	17.1				
	6/78	14.5		0.2		
	8/78	45.3				
	9/78	33.3				
	12/78	57.3	0.3		0.2	
	6/79	37.3				
	7/79	33.3				
	8/79	42.5	0.8			
	9/79	1.0	0.3	0.3		40.2

(continued)

TABLE 7 (continued)

Species	Date	Field	Treatment			
			0°C	2°C	4°C	6°C
Argopecten irradians	8/77	11.5		0.2		
Botryllus schlosseri	6/77		844	135	7.2	0.2
	6/77	33.3	2516	1346	5.8	3.8
	7/77	6.3	97	240	18.0	0.7
	8/77	1.6	16.2	40	3.0	0.1
	6/78	17.8			19.7	
	7/78	12.0	46.8	13.0	1.5	
	6/79	4.5	60.2			
Molgula manhattensis	4/77	11.3	0.1	0.8		
	8/77		3.3	1767	0.8	
	9/77	31.3		17.2	41.2	
Perophora viridis	8/77	2.5	15.0	28.5		
	6/78				15.7	
	7/79		90.5		57.0	
	8/79		15.1			
	10/79		93.3	13.7		
	11/79		15.6			

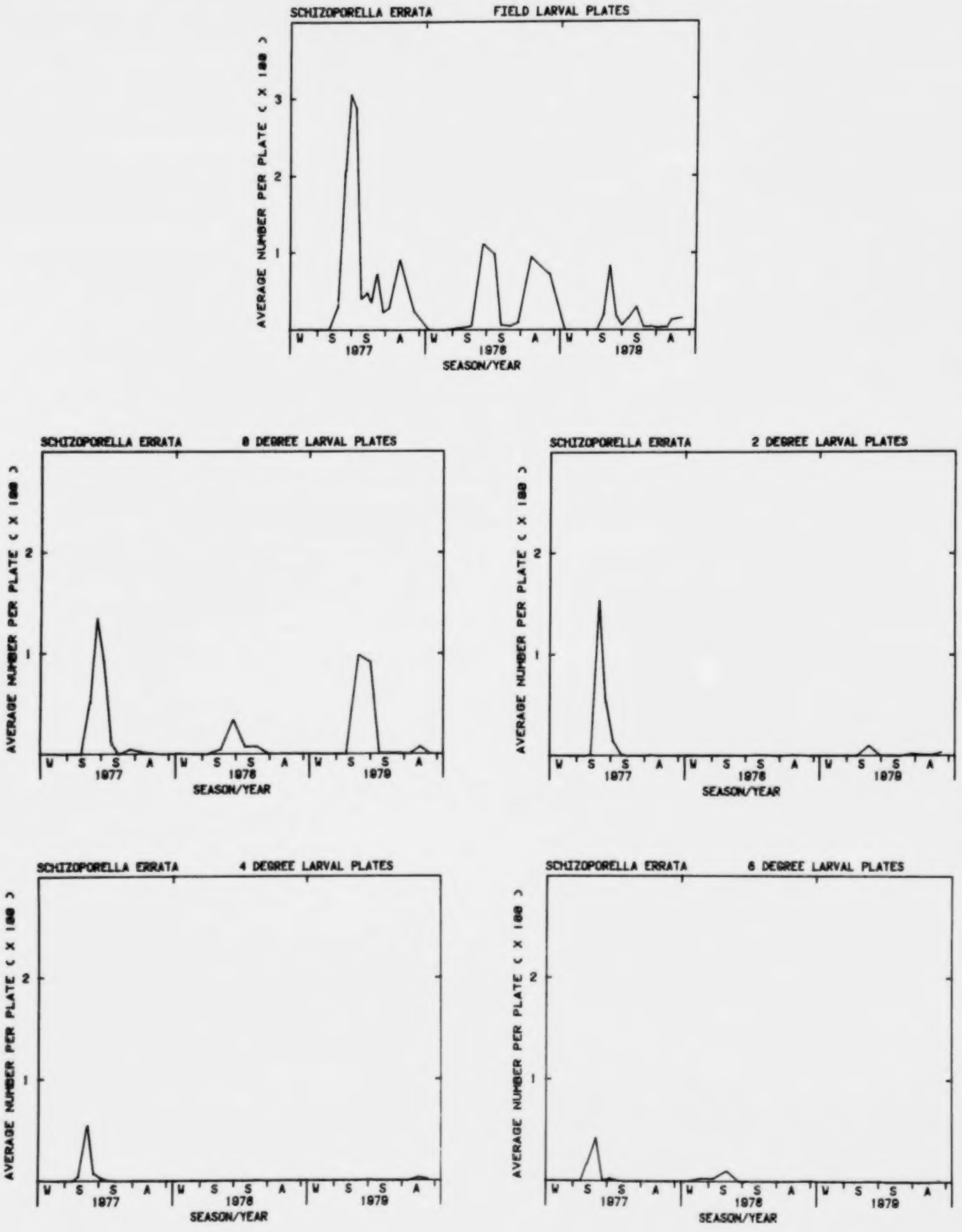

Figure 2. Average number of encrusting bryozoan, Schizoporella errata, recruited per larval plate through time for five treatments.

times greater than in the laboratory at 0°C, and in 1979 it was approximately the same. Greatest recruitment in all treatments occurred during 1977. The laboratory system decreased recruitment during 1977 and 1978, but not during 1979 (compare field with 0°C data in Figure 2). Elevated temperature had a significant negative effect on recruitment: numbers of recruits decreased progressively as temperature increased. *Bugula neritina*, an erect bryozoan, was recruited primarily during the spring with some late summer and autumn recruitment (Figure 3). As seen by comparing the field with the 0°C laboratory data (note scale differences in Figure 3), the experimental system caused a decrease in recruitment of *B. neritina*; although increasing temperature in the laboratory generally increased the number recruited, particularly in the spring, such that the 2°C, 4°C and 6°C plates were similar to field plates (except in spring 1979). There were differences between years in the numbers of *B. neritina* recruited; however, these differences were not consistent among treatments. *Bugula avicularia*, another erect bryozoan, showed a similar recruitment pattern to *B. neritina* (Figure 4). However, autumn recruitment of *B. avicularia* was relatively more important than autumn recruitment of *B. neritina*. Maximum recruitment occurred during the spring and autumn with minimum to no recruitment in midsummer and winter. Recruitment of *B. avicularia* was generally much greater in the laboratory (0°C plates) than in the field. Thus the laboratory system enhanced recruitment of this species. However, in the autumn of 1979 recruitment was somewhat greater in the field than in the laboratory. Recruitment numbers were similar at 0°C, 2°C, and 4°C, but somewhat greater at 6°C in the spring of 1977 and 1979. At 4°C and 6°C, maximum recruitment occurred earlier in the spring of 1977 and 1979, suggesting that elevated temperatures caused earlier recruitment of this species. Significant year-to-year differences occurred in the numbers of recruits, with the least recruitment occurring in 1978 (except in the 2°C treatment) and a maximum in 1979.

Other bryozoans occurred on plates but less often and in fewer numbers. *Electra monostachys* recruited an average of 10 or more times per plate for a few periods (winter and spring of 1978, 1979) (Tables 6 and 7).

Three species of annelid worms appeared in significant numbers on the larval plates during the course of the study. For *Spirorbis borealis*, a very small serpulid worm, recruitment was the most unusual of all species encountered (Figure 5). Throughout the summer of 1977 the numbers of *S. borealis* on field and laboratory 0°C plates were not significantly different. However, by October 1977 the 0°C laboratory plates were recruiting significantly greater numbers than the field plates and continued to do so for almost every period. The presence or absence pattern of recruitment of *S. borealis* at elevated temperatures in the laboratory was similar to ambient temperature plates. Although the differences are difficult to discern because of the changes in scale in Figure 5, recruitment to the 2°C plates was significantly greater than that on the field plates by July 1977; and at 4°C and 6°C increased recruitment occurred two months earlier. In general, the numbers recruited on the laboratory plates increased from 0° to 4°C with a decrease at 6°C. Recruitment at 6°C was reduced during the late summer when temperatures were greatest and periods of no recruitment were observed. *S. borealis* broods its larvae and releases them at a stage when they are ready to

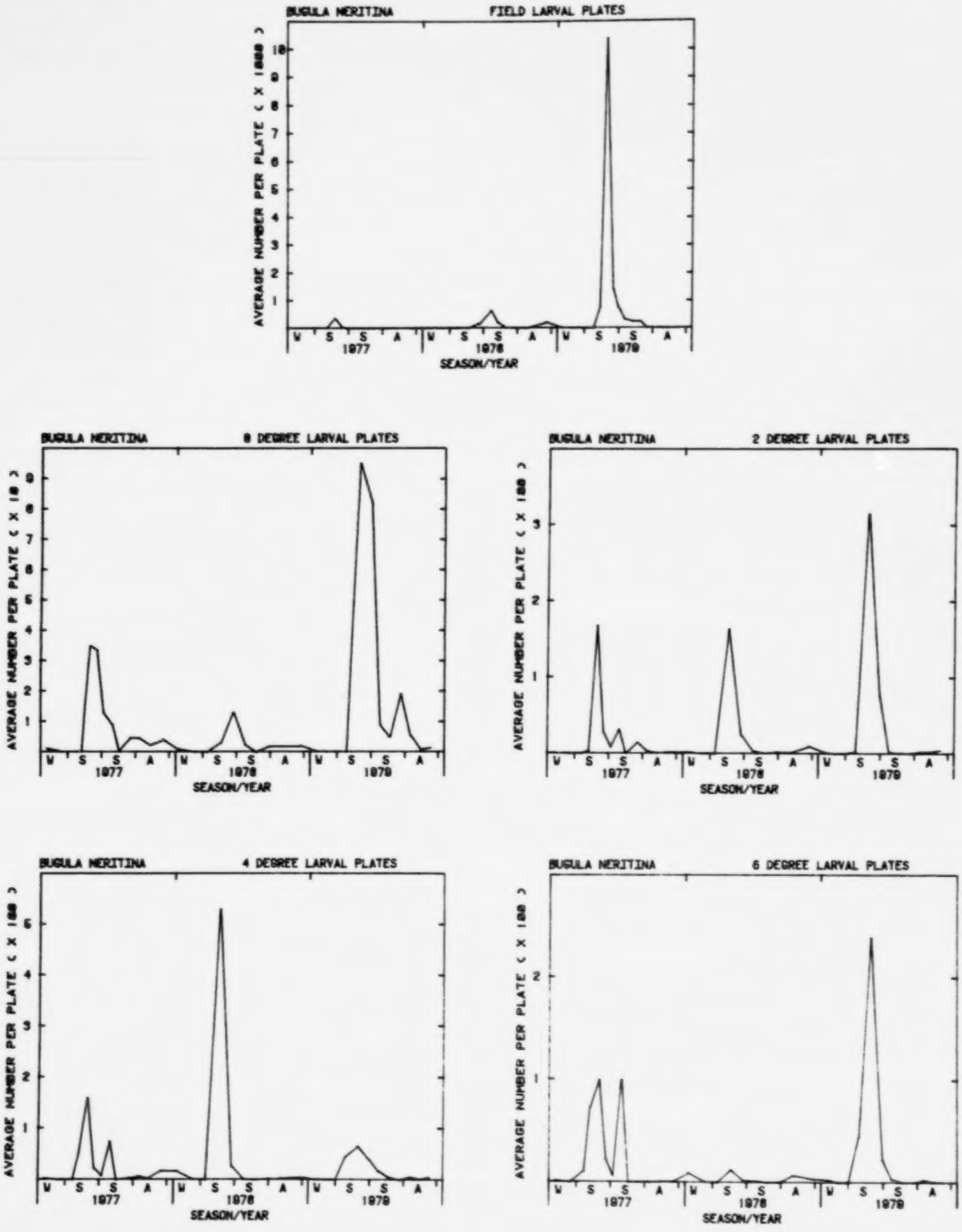

Figure 3. Average number of erect bryozoan, Bugula neritina, recruited per larval plate through time for five treatments.

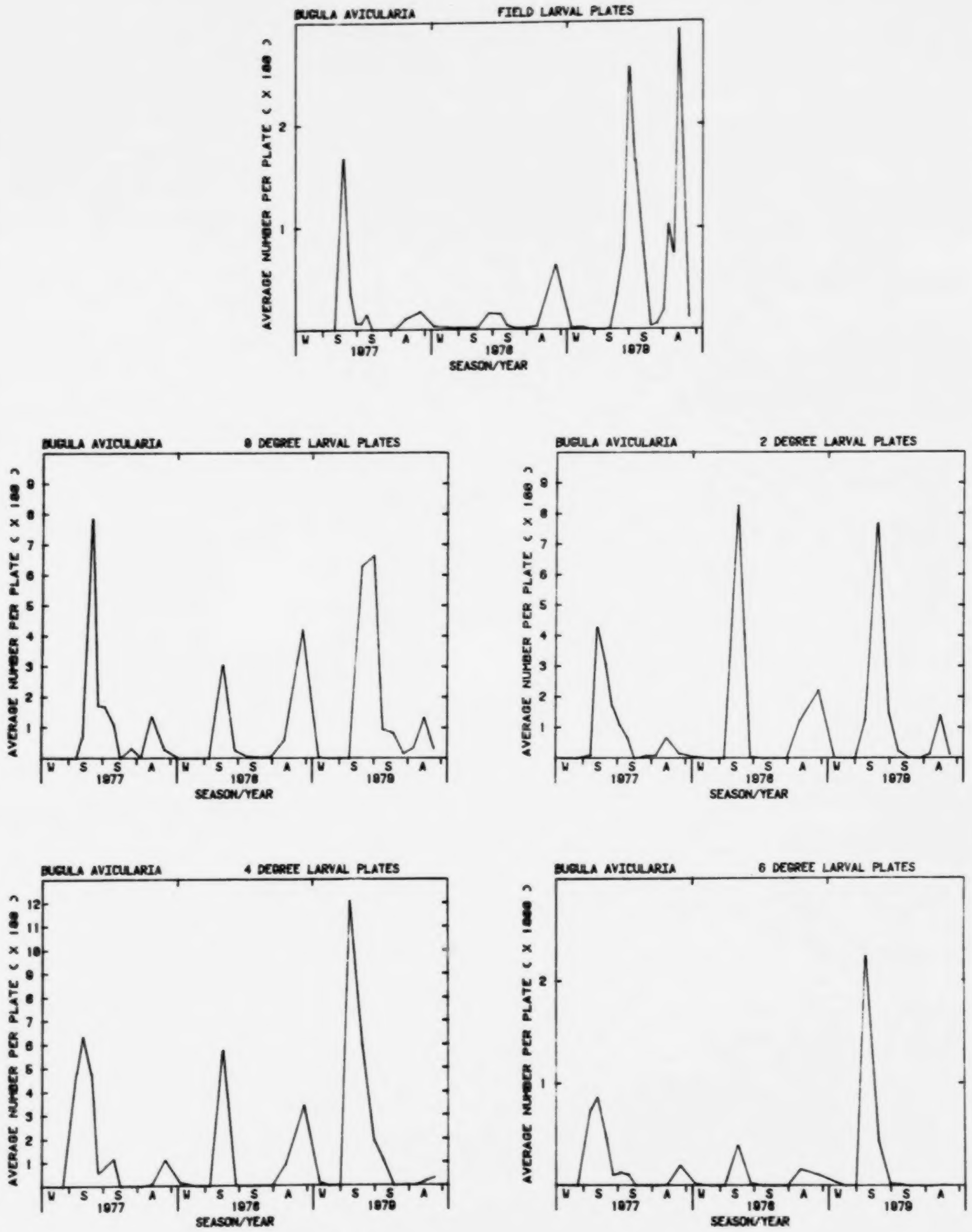

Figure 4. Average number of erect bryozoan Bugula avicularia recruited per larval plate through time for five treatments.

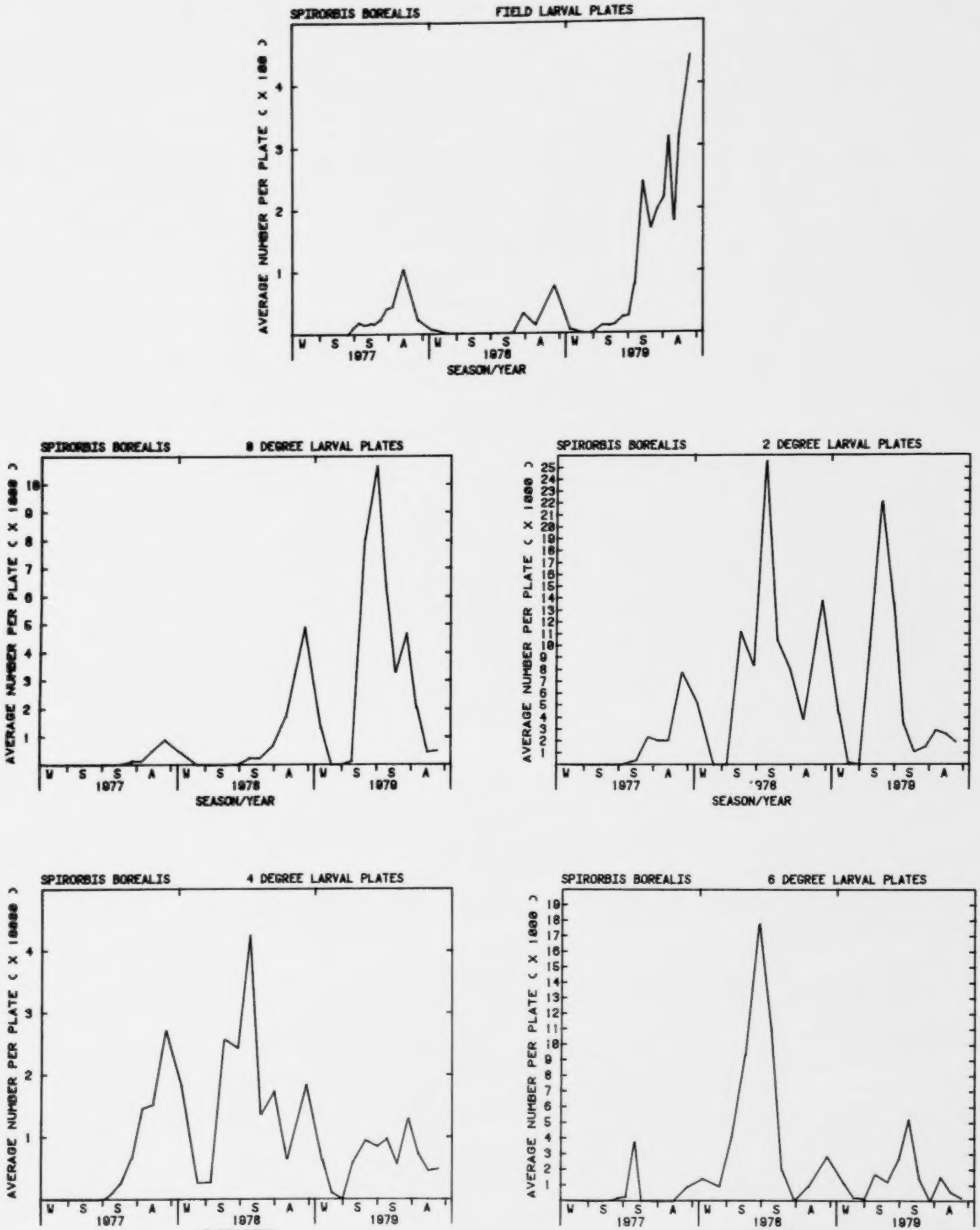

Figure 5. Average number of the polychaete, Spirorbis borealis, recruited per larval plate through time for five treatments.

settle (within 15 min to 2 hours). Thus, the increased numbers (to a maximum of greater than 40,000) of *S. borealis* observed on laboratory plates can be explained as a self-recruiting phenomenon within the laboratory system. Even in 1979 when the frequency of routine cleaning of the sides and bottom of the tanks was increased, which reduced the adults available to provide recruits, self-recruitment still could occur since the permanent community plates in the tanks had large numbers of *S. borealis*. The maximum *Spirorbis* density was approximately two individuals per mm^2 (4°C, summer 1978), a density which probably would influence the recruitment of other species. Increasing temperature probably had the primary effect of increasing the growth rate and reducing the generation time of *S. borealis*, which may explain the greater recruitment at 4°C. However, decreased recruitment in late summer at 6°C might have been the result of significant adult mortality due to the high temperatures during this period.

A much larger worm, *Hydroides dianthus*, occurred regularly on both field and laboratory larval plates, although it occurred in fewer numbers than *S. borealis* (Figure 6). *H. dianthus* recruited in approximately the same numbers to a maximum of approximately 600 per plate on field plates in the summer of all three years. Recruitment in the laboratory was much less than that in the field. In the laboratory the higher temperatures (4° and 6°C) resulted in an earlier recruitment in 1978 and 1979. Even though *H. dianthus* did not recruit in large numbers on laboratory plates, its presence from year to year was predictable.

Sabellaria vulgaris, a sabellid worm, showed moderate and consistent recruitment on field plates beginning in early summer and continuing through autumn and into early winter (Table 7). Peak numbers occurred in autumn and early winter, suggesting an early autumn spawning. This species occurred significantly (> 10 per plate) in the laboratory only once (September 1979, on the 6°C plates).

Two species of bivalve molluscs were seen on the larval plates in significant numbers. *Crassostrea virginica*, the common oyster, appeared on the larval plates during the summer periods (Figure 7); it was usually recruited in slightly greater numbers on field plates than on laboratory plates. In the laboratory there was little apparent influence of temperature on recruitment. Of all the species encountered, *C. virginica* recruitment appeared to be the least influenced by either the laboratory system or the increasing temperatures within the system. *Argopecten irradians*, the bay scallop, recruited once (August 1977) in significant numbers on field plates but never on laboratory plates (Table 7).

Two arthropods were recruited on the larval plates during the course of the experiment. *Balanus* spp. is a complex of two or three different barnacle species which are difficult to distinguish from each other as postlarval recruits (Figure 8). Although there were great variations in the numbers recruited, barnacles appeared throughout the year with maximum recruitment usually occurring in the spring and summer. The numbers of barnacles recruited on field plates were two to three orders of magnitude greater than in the laboratory. In the laboratory recruitment was generally greater at

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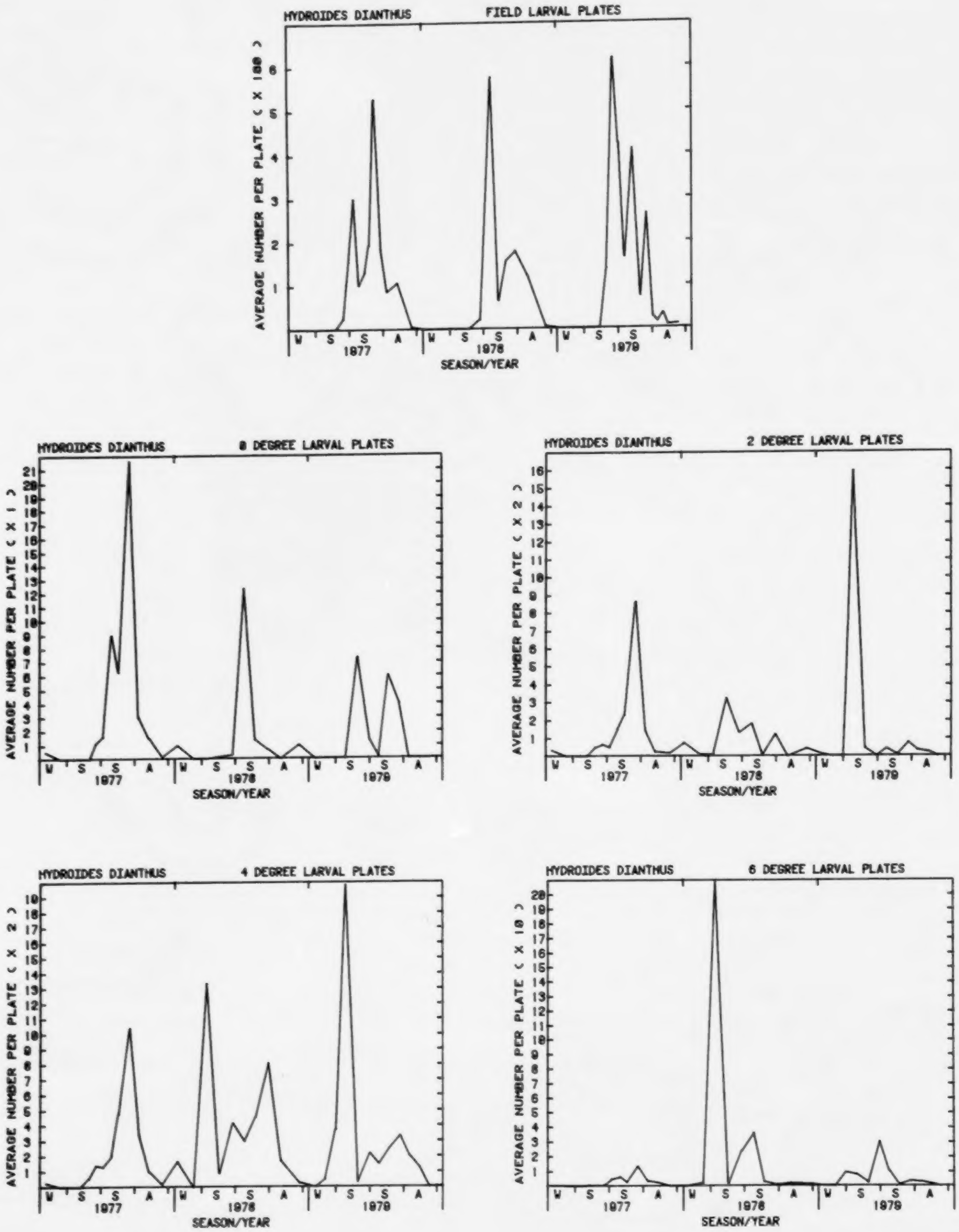

Figure 6. Average number of the polychaete, Hydroides dianthus, recruited per larval plate through time for five treatments.

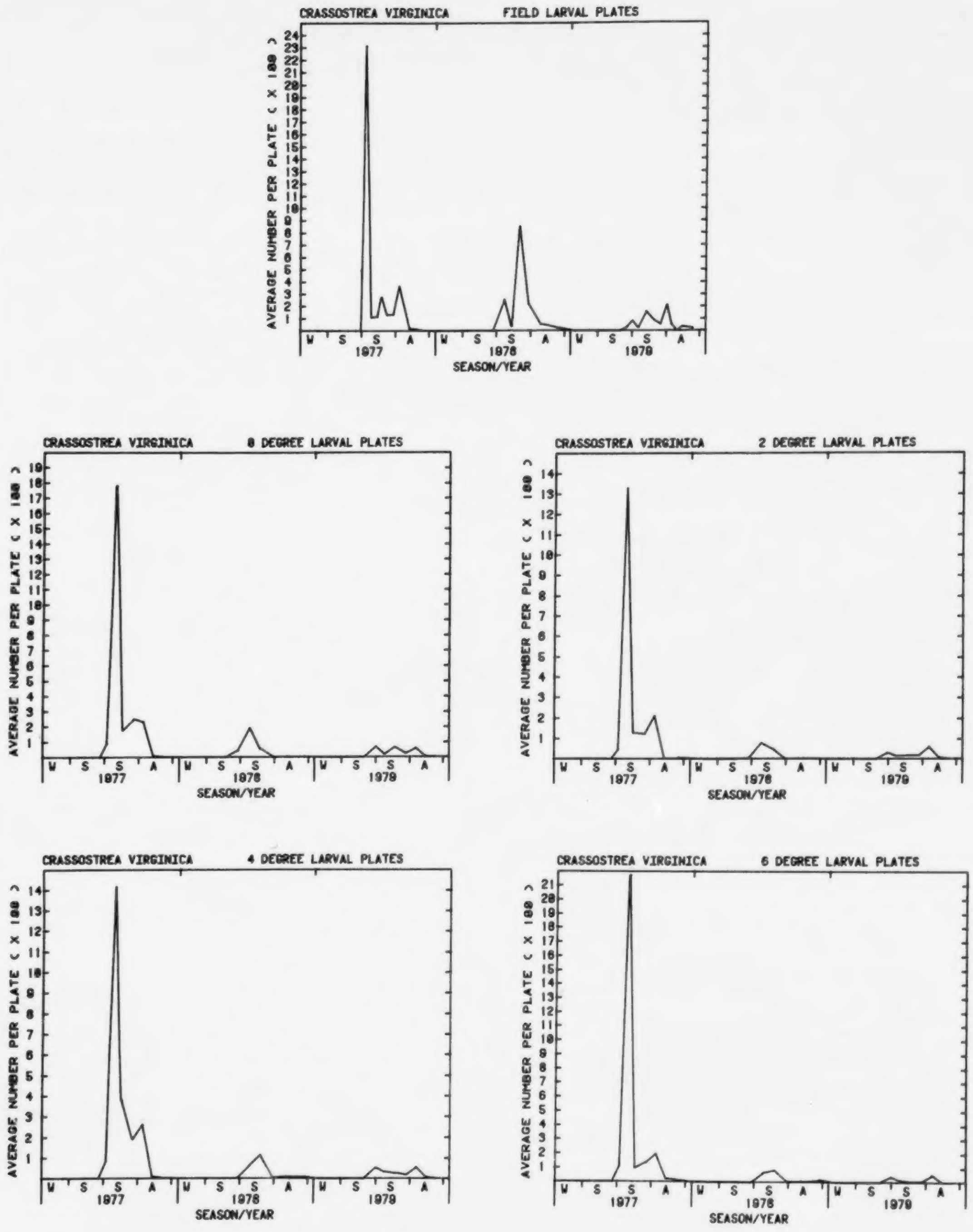

Figure 7. Average number of the oyster, *Crassostrea virginica*, recruited per larval plate through time for five treatments.

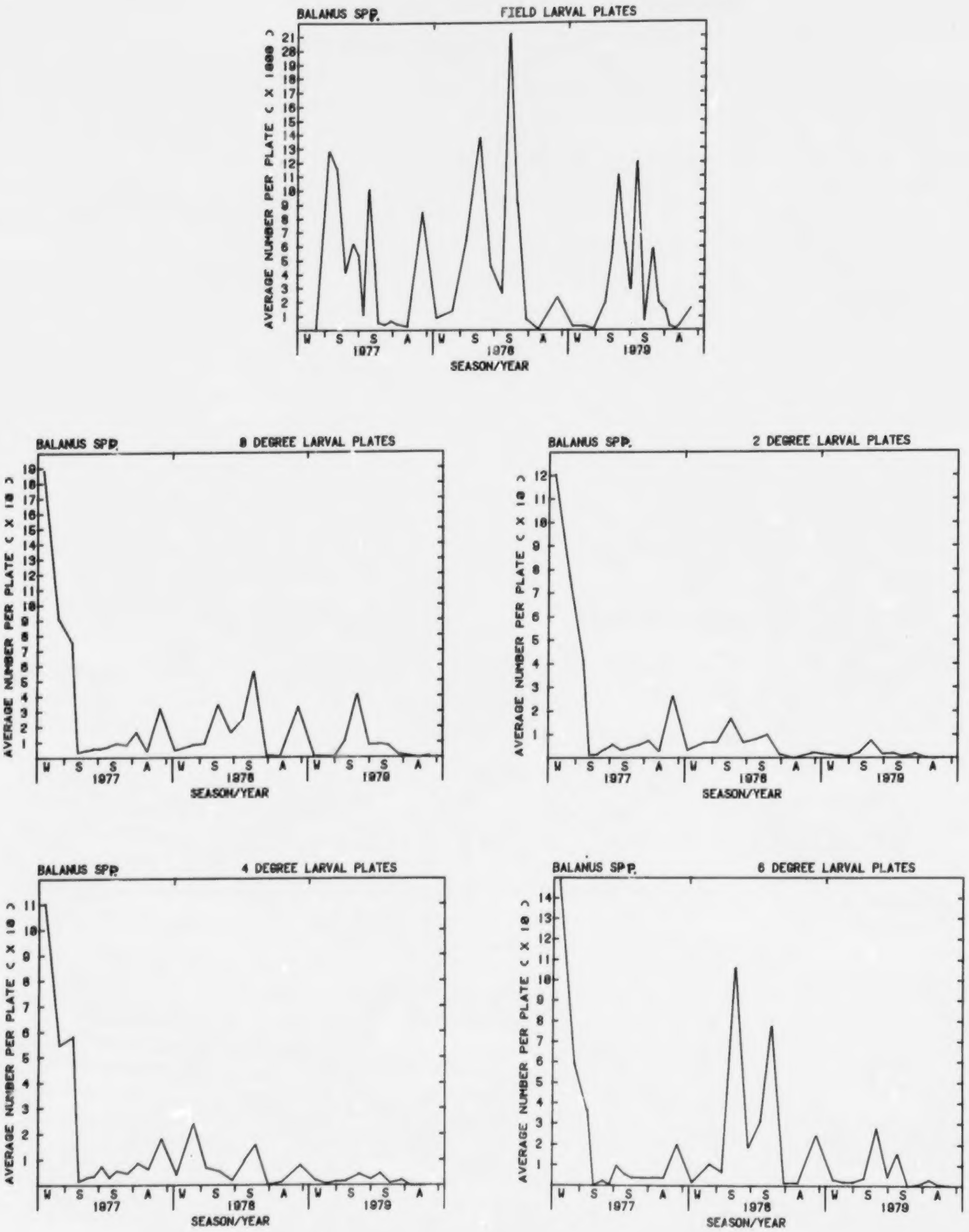

Figure 8. Average number of barnacles, Balanus spp., recruited per larval plate through time for five treatments.

0°C than at 2°C or 4°C, but not greater than at 6°C. The presence of an assemblage of barnacle species makes further interpretation of these data impossible, particularly with reference to the effects of temperature. It is apparent that in the field barnacles are the first and most numerous group to appear on the available open space on hard substrate, but they do not exclude other species from settling.

An amphipod, *Corophium acherusicum*, was the only nonsessile species which appeared on larval plates in significant numbers (Figure 9). *C. acherusicum* constructs a small mud tube on the surface of both hard and soft substrates and appears to survive best in situations where it is protected from the grazing activities of predators. This species appears to recruit year round except for the coldest months of the year. Recruitment in the laboratory began in the spring of 1977 and reached a peak in the spring of 1978. *C. acherusicum*, like *Spirorbis borealis*, broods its young; thus self-recruitment undoubtedly occurred in the laboratory tanks. On field plates recruitment of *C. acherusicum* began in the summer of 1977. Recruitment in the laboratory was much greater than that in the field (note the scaling factor in Figure 9). Temperature appeared to have little predictable influence on the recruitment of *C. acherusicum* except that at 6°C there was a decrease in recruitment in midsummer and an increase in the cooler seasons of the year over that seen at 0°C. It appears that increased frequency of cleaning of the tanks during 1979 may have reduced recruitment of this species significantly in all experimental tanks compared to the previous two years.

Five species of tunicates were observed to recruit in significant numbers on larval plates during the experiment. In addition, a group labeled "unknown tunicate" was counted; this was probably one or more of the three most common solitary tunicates. *Styela plicata* recruited during the warmer seasons (spring and autumn) in the field, but not on laboratory plates (Figure 10). *S. plicata* is a dominant in the fouling community at Beaufort and its failure to recruit in significant numbers in the laboratory would have a considerable consequence for the type of community which developed on the permanent laboratory plates.

Ascidia interrupta showed the same pattern of recruitment as *S. plicata*; however, the numbers recruited were far fewer (Figure 10, note the scaling factor). *A. interrupta* recruited significantly once (August 1977, 173 per plate) in the laboratory on 2°C plates.

Recruitment of the "unknown tunicate" is difficult to interpret (Figure 11). The timing of peak recruitment for the unknown tunicate on field plates in 1978, however, corresponds with the peak for *Styela plicata* (Figure 10), while the peaks on the laboratory plates correspond with the peak for *Ascidia interrupta* (Figure 10). Hence, it is possible that the unknown field tunicate was predominantly *S. plicata* which was never observed on laboratory plates, while the unknown laboratory tunicate was predominantly *A. interrupta*.

Botryllus schlosseri, a colonial tunicate, recruited in the early summer (Table 7). Recruitment was greatest at 0°C and 2°C, less at 4°C and in the

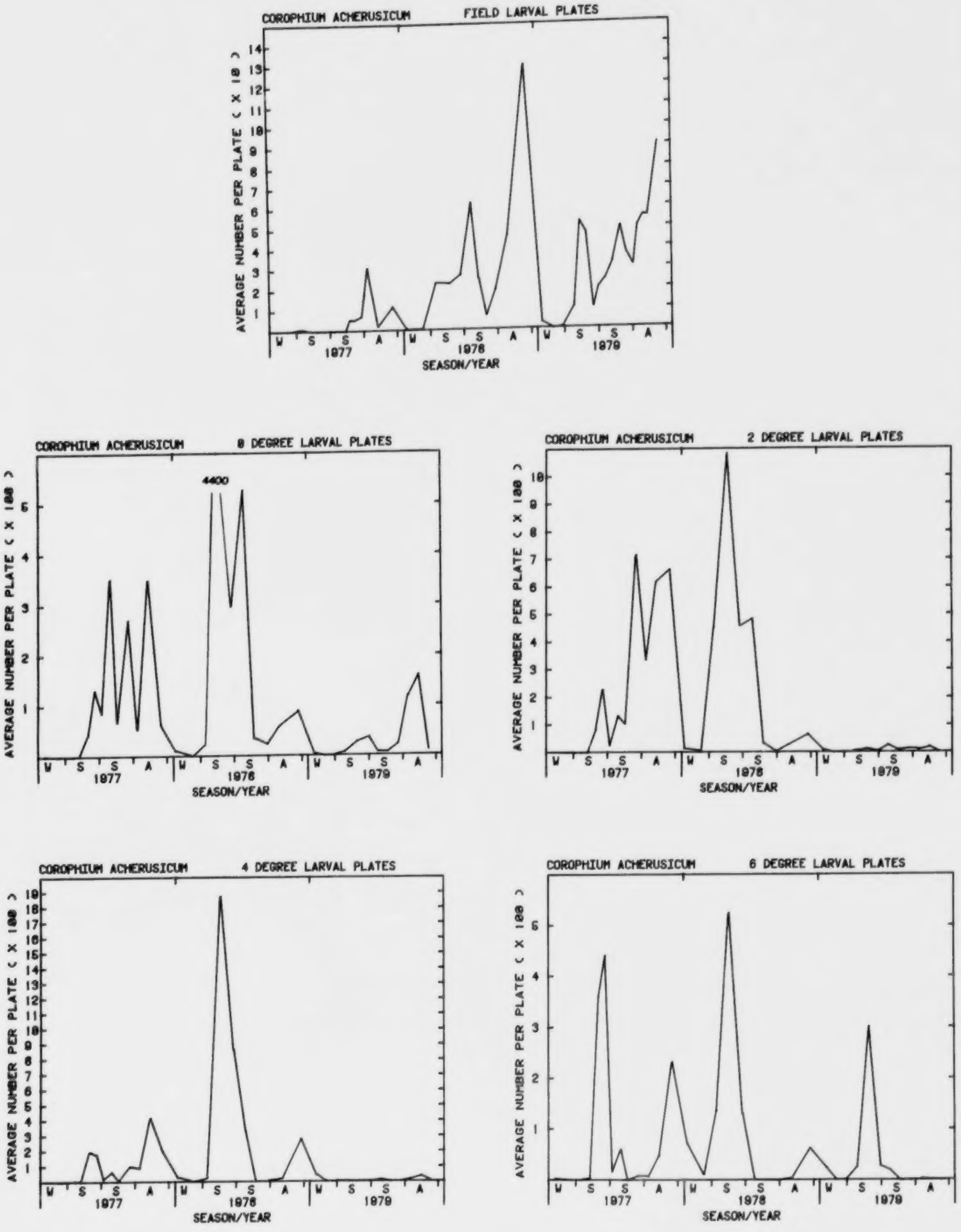

Figure 9. Average number of the amphipod, *Corophium acherusicum*, recruited per larval plate through time for five treatments.

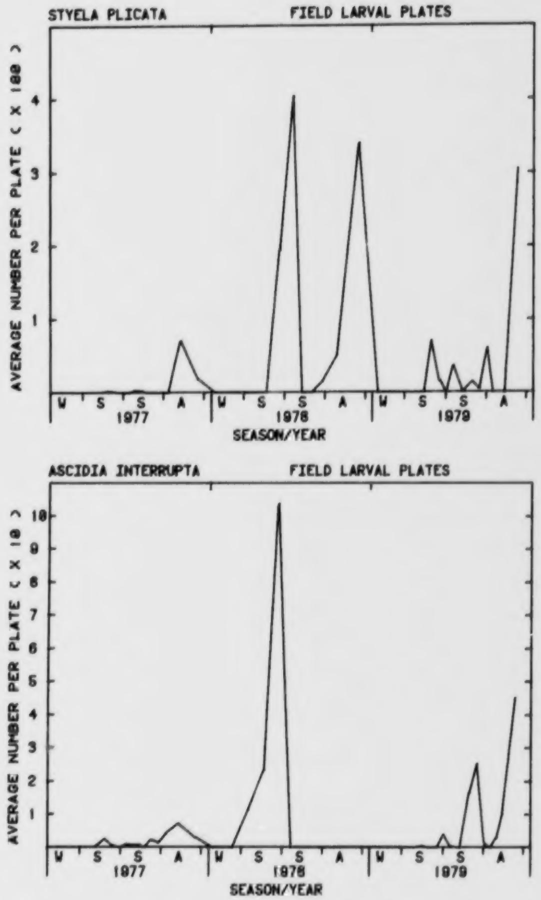

Figure 10. Average number of the tunicates, *Styela plicata* and *Ascidia interrupta*, recruited per larval plate through time for the field treatment.

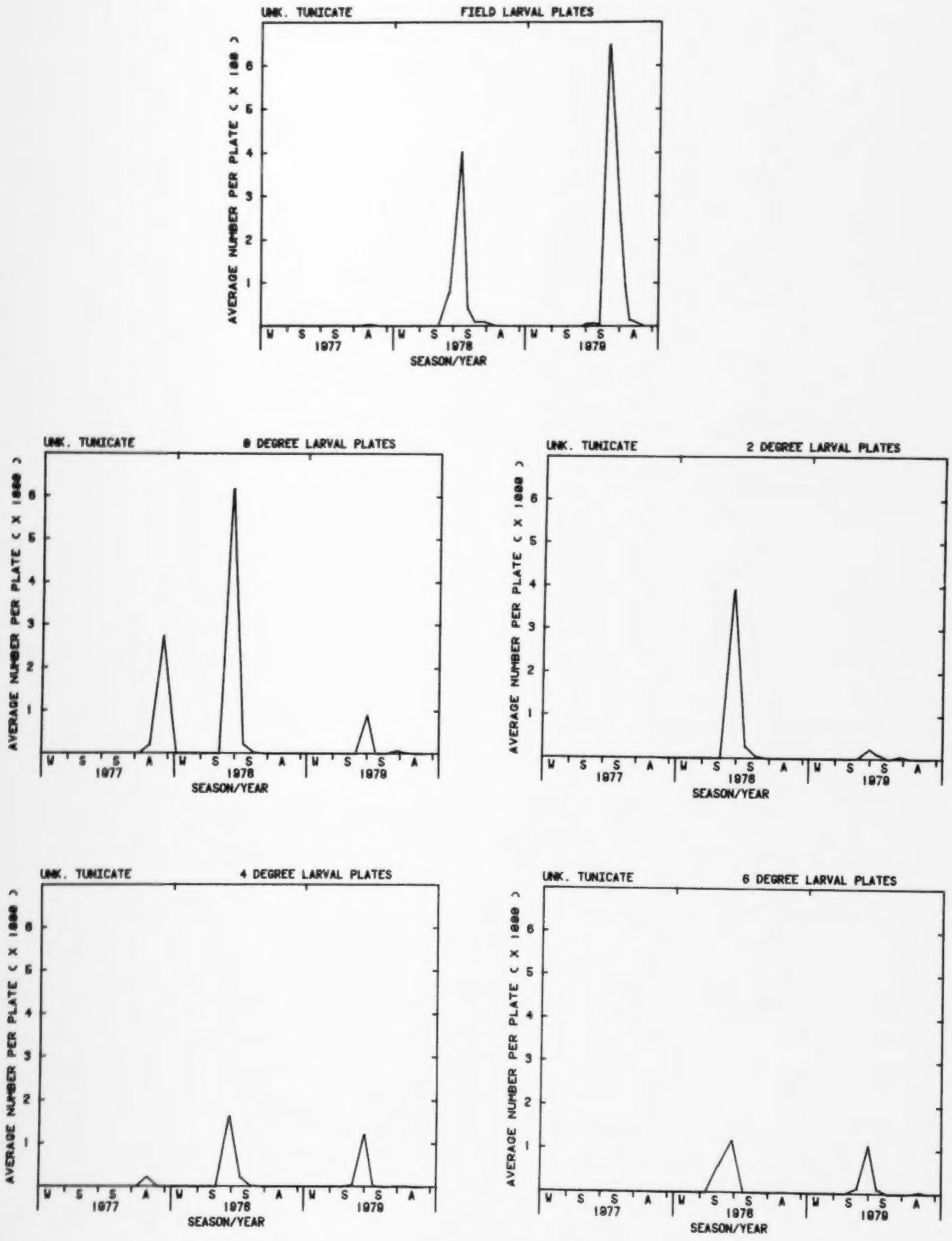

Figure 11. Average number of an unidentifiable tunicate species recruited per larval plate through time for five treatments.

field, and least at 6°C. Thus, the laboratory system appeared to enhance recruitment, while elevated temperatures caused a reduction in recruitment.

Molgula manhattensis, a solitary tunicate, recruited in August 1977 in large numbers (1767 per plate) at 2°C (Table 7). This species recruited in much lower numbers in the field, at 0°C, and at 4°C in 1977; however, it was never observed in significant numbers in 1978 or 1979.

Perophora viridis recruited in significant numbers on the 0°C plates in the summers of 1977 and 1978 and in autumn of 1979 (Table 7). It never recruited in the field or at 6°C in significant numbers.

Data on larval recruitment of the species discussed above are summarized in Table 6. In a comparison of field plates to each group of laboratory plates over the three-year period, there was a significant difference (positive or negative) between field and laboratory treatments in 70 - 83 percent of the total number of time periods in which recruitment of the listed species occurred. Thus, it can be concluded that the laboratory system had a very strong influence on the numbers or the time, or both, when most of the species were recruited. In comparing differences between temperature treatments, it was observed that the greater the temperature differential between treatments, the greater number of cases in which recruitment was different. In cases where the differential was 2°C, there were 40 percent (0°C - 2°C), 38 percent (2° - 4°C), and 44 percent (4° - 6°C) differences (an average of 40.7 percent). At the 4°C temperature differential there were 52 percent (0° - 4°C) and 55 percent (2° - 6°C) differences (an average of 53.5 percent). At the 6°C temperature elevation there was a 62 percent (0° - 6°C) difference. Thus it appears that even a small elevation in temperature will result in a very significant change in the numbers of individuals of many species which will recruit to a new substrate at any one time period.

Changes in the Recruiting Community

In the preceding section significant differences between treatments have been demonstrated regarding the abundance of many of the species recruited on larval plates. However, the question of whether recruitment community differences exist is answered by an analysis of the similarities in community structure between various treatments for single time periods. If the relative numbers (i.e. percent composition) of individuals are similar between treatments, then the communities are similar even though the absolute densities may be very different. The technique of cluster analysis of similarity matricies was used to examine community structure of larval plates. There were 35 observational periods, each approximately one month in duration, during the three years of the experiment. Some experimental plates were lost due to overheating and nonoverlap in sampling periods. Two separate comparisons were made. The first was a comparison of field plates (four replicates) with laboratory plates held at ambient temperature (six replicates) for 29 time periods; the second was a comparison of all laboratory plates (six replicates at each of the four temperature treatments) for 27 time periods.

Table 8 is a summary of results of the cluster analysis. Field plates recruited a community which was, in general, very different from that in the laboratory. In 25 of the 29 time periods, similarities (labeled "both") between the field and the laboratory 0°C plates were less than 0.30 (< 0.1 + < 0.2 + < 0.3). In only two cases, both late winter samples, were communities similar (column labeled < 1.0). These were times when very few species were recruited and when barnacles were dominant on both field and laboratory plates. Thus the system itself (in the absence of temperature modifications) caused a change in the community of recruits. Furthermore it can be seen from Table 8 that variability among communities on separate plates in the laboratory at 0°C (only 9 of 29 clustering at > 0.90) was greater than variability among field communities (25 of 29 clustering at > 0.90).

Relative effects of different temperature treatments within the laboratory were less apparent than field-versus-laboratory differences. Although not indicated in Table 8, it was rare for communities from any one temperature treatment to cluster together at any level of similarity without one or more plates from other treatments occurring in the same group. On three occasions (winter) all plates clustered at > 0.9 level of similarity (Table 8). These communities were composed primarily of barnacles. The data which show clustering by individual plates are not presented because the structure of the groupings was complex and no patterns related to treatment were persistent through time nor could they be related to season. Thus, the effect of temperature on the structure of the community of larval recruits appears to be unpredictable. Data presented in Table 8 indicate that variability of community structure of 0°C and 6°C communities was greater than that of 2°C and 4°C communities. The reason for this is not clear.

Although no diversity indicies have been calculated for larval recruitment, the average number of species per plate (Figure 12) gives an indication of the changes in diversity of the communities recruited as a function of time and treatment. In the field the number of species recruited goes from a winter minimum of one to three species per plate, to a late spring or summer maximum of 13 to 14. There is a suggestion, at least in 1977 and 1978, of a slight midsummer decrease in number of species recruited. In the laboratory at ambient temperatures the number of species recruited per plate reached a minimum of approximately one during the late winter and a maximum of approximately 10 in the summer. It appears that the seawater system caused a significant (approximately 30 percent) decrease in the maximum number of species recruited in the laboratory compared to the number recruited on field plates. Within the laboratory system, increasing temperature had a dramatic effect on the number of species recruited. There was very little difference between 0°C and 2°C plates, except in the late winter at 2°C when there was a slight increase in the number of species recruited. At higher temperatures there is a very significant change in the recruitment pattern. The maximum number of species recruited decreased, the minimum number increased, and a strong semiannual pattern emerged in which minimum recruitment occurred in both the midwinter and midsummer with maximum recruitment of species occurring in the spring and autumn.

TABLE 8. RESULTS OF CLUSTER ANALYSIS OF LARVAL RECRUITMENT DATA. THE TABLE LISTS THE NUMBER OF TIMES THAT ALL PLATES IN A PARTICULAR TREATMENT CLUSTERED TOGETHER AT THE SIMILARITY INDICATED (0 = NO SIMILARITY; 1.0 = IDENTICAL). BOTH = FIELD + 0°C LABORATORY PLATES. ALL = 0°C + 2°C + 4°C + 6°C PLATES.

	Similarity Level									
Group	< .1	< .2	< .3	< .4	< .5	< .6	< .7	< .8	< .9	< 1.0
Field	0	0	1	0	1	0	0	2	0	25
0°C	2	0	4	0	2	1	2	4	5	9
BOTH	15	1	9	0	1	0	1	0	0	2
0°C	2	3	2	0	2	1	2	4	4	7
2°C	0	1	0	0	1	1	2	4	2	16
4°C	0	0	0	0	1	1	0	2	1	22
6°C	1	2	3	1	2	1	1	2	4	10
ALL	4	5	4	3	2	2	1	2	1	3

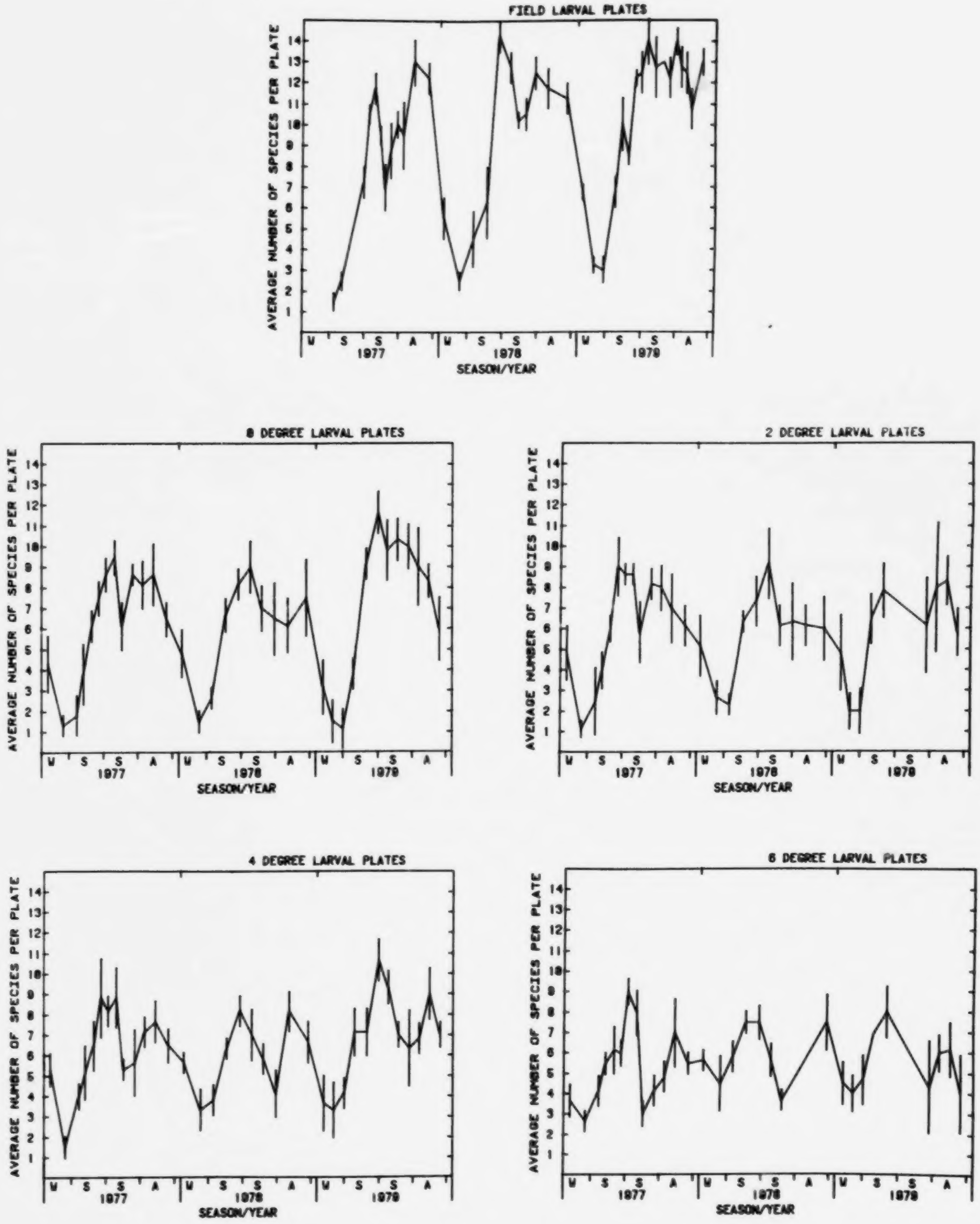

Figure 12. Average number of species recruited per larval plate through time for five treatments. Vertical lines are ± one standard deviation.

PERMANENT PLATE COMMUNITIES

Summary

As with larval recruitment, the laboratory system appeared to have a great influence on the success or failure of individual species in the permanent plate communities; within the laboratory system temperature treatment effects were also evident. Seventeen of the 28 species reported occurred with a maximum mean cover of approximately 10 percent or greater at least once in one treatment during the experiment.

The most important species on the field plates were Schizoporella errata, Styela plicata, and Bugula neritina, none of which was significant (greater than 10 percent cover) in the laboratory. By the end of the experiment S. errata had almost disappeared and several other species (Crassostrea virginica, Haliclona loosanoffi, and Aiptasia pallida) had become more important. Of these latter three species only C. virginica had significant coverage on laboratory plates.

Within the laboratory the three most important species were Crassostrea virginica, Spirorbis borealis, and Corophium acherusicum; and Perophora viridis, Bugula avicularia and Molgula manhattensis were important seasonally. The sponge Halichondria bowerbanki was increasing in its abundance at the end of the experiment (except at 6°C), and if the experiment had continued it probably would have become a major species on many of the laboratory plates.

Within the laboratory the effect of increasing temperature on individual species was mixed. Little or no effect was observed with several species (Hydroides dianthus, Geukensia demissa), while in other species (Crassostrea virginica, Perophora viridis) higher temperatures (particulary 6°C during the summer) inhibited growth or caused mortality. Spirorbis borealis was most abundant at 2°C and 4°C with lower percent cover at 0°C and 6°C. One of the important species, Corophium acherusicum, was unpredictable in its percent cover. In the summer of 1979 C. acherusicum in the 4°C and 6°C experiments decreased dramatically in percent cover when compared with the 0°C and 2°C. However in the summer of 1978 the decrease in percent cover occurred in all treatments. In the winter of 1978 - 1979 there was a large increase in percent cover in the 6°C treatment, a slight increase in the 4°C treatment and very little increase at 0°C and 2°C. Moreover, in the late summer and autumn of 1979 there was an increase in abundance at 0°C which occurred only slightly in the other treatments.

In comparing Series "A" with Series "B" results it was observed that the significant differences which had occurred between series in percent cover by some species (Crassostrea virginica, Hydroides dianthus, Spirorbis borealis) in some treatments in 1977 had disappeared by the end of the experiment in 1979. For the percent cover data at the end of the experiment, the Series "A" and Series "B" treatments at each temperature were indistinguishable from each other.

The influence of the experimental system and temperature changes on percent cover within the system were species specific and included positive, negative, neutral, and mixed effects depending upon the species being considered. No single generalization can be made concerning the influence of temperature on individual species.

General Results

Table 9 lists 28 species which, as a minimum, occupied 10 percent of the cover at least once on one of the 75 permanent plates during the course of the experiment. Although 15 other species were identified on permanent plates; they occurred infrequently or in low numbers, or both, and therefore are not discussed further. These species included: the sponges *Haliclona permolis*, *Microciona prolifera*, and *Lissodendoryx isodictyalis* and four unidentified sponge species; an unidentified anemone; the bryozoan *Electra monostachys*; the polychaetes *Amphitrite ornata* and an unidentified sabellid; the molluscs *Anomia simplex*, a jewel box of the family Chamidae, *Crepidula* sp., and an ark shell of the family Arcidae.

The relative importance and temporal pattern of appearance of each of the 28 significant species are discussed below. For the purpose of summarizing the data for each species, a mean and standard deviation in the percent cover have been calculated for each of the nine treatments (one field, four Series "A", and four Series "B") for each time period. These data are presented in tables when the species occurred mainly in one treatment, when the frequency of occurrence was low, or when the mean percent covers were low. Series "A" and "B" data are presented separately. To convert consecutive day to date see Table 2. When a species occurred frequently and with significant percent cover (>10 percent) the data are presented as figures.

Porifera

Aplysilla sulfurea, an encrusting sponge occurred in low abundance on laboratory plates during two sampling periods in Series "A" and 10 periods in Series "B" (Table 10). This species occurred on one plate with 16 percent cover in December 1978 (Day 705); mean percent cover, however, was always less than one percent.

Haliclona loosanoffi, an encrusting species, first appeared on field plates January 1979, Day 735 (Table 11). This species appeared in all laboratory treatments except 6°C. In general, mean abundance increased to late summer of 1979 (Days 950 and 980) and showed a slight decrease toward the end of the experiment in November 1979 (Day 1035). The maximum mean abundance (11.1) occurred on field plates. The high standard deviation relative to mean abundance is due to the fact that *H. loosanoffi* occupied only a few of the plates in each treatment. For instance in August 1979 (Day 950) one of the plates in Tank 4 (a 2°C treatment) had 28 percent cover of *H. loosanoffi* while the other five plates had zero percent cover. *H. loosanoffi* was slow to become established on plates, but once established it spread rapidly and was a significant competitor for space. Furthermore, the data suggest that at the

TABLE 9. LIST OF SPECIES OBSERVED ON ONE OR MORE PERMANENT PLATES, OCCUPYING A MINIMUM OF 10 PERCENT COVER DURING ONE OR MORE SAMPLING PERIODS

Porifera
- *Aplysilla sulfurea*
- *Haliclona loosanoffi*
- *Halichondria bowerbanki*
- *Leucosolenia canariensis*
- *Leucosolenia* sp.

Coelenterata
- Hydrozoa
  - *Eudendrium ramosum*
  - *Pennaria tiarella*
- Anthozoa
  - *Aiptasia pallida*
  - *Astrangia danae*
  - *Diadumene leucolena*

Bryozoa
- *Anguinella palmata*
- *Bugula avicularia*
- *Bugula neritina*
- *Schizoporella errata*

Annelida
- *Hydroides dianthus*
- *Sabellaria vulgaris*
- *Spirorbis borealis*

Mollusca
- *Argopecten irradians*
- *Crassostrea virginica*
- *Geukensia demissa*
- *Modiolus americanus*

Arthropoda
- *Balanus* spp.
- *Corophium acherusicum*

Urochordata
- *Ascidia interrupta*
- *Botryllus schlosseri*
- *Molgula manhattensis*
- *Perophora viridis*
- *Styela plicata*

TABLE 10. APLYSILLA SULFUREA PERCENT COVER

Series A

	0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
950				9	.19	.61	9	.02	.11			
980				9	.07	.28						

Series B

	Field			0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
540				9	.09	.29									
575				9	.07	.35									
670							9	.04	.23						
705							9	.50	2.0						
735							9	.09	.38						
765				9	.02	.12	9	.02	.14	9	.09	.35			
792										9	.01	.05			
925													8	.03	.15
950							9	.70	1.8						
980							9	.16	.40						

TABLE 11. HALICLONA LOOSANOFFI PERCENT COVER

Series A

	0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
735							9	.04	.22			
765							9	.05	.32			
850				9	.20	1.2						
925				9	.60	3.1						
950	9	.43	1.6	9	1.5	5.2						
980	9	1.2	5.1	9	2.8	7.9						
1005	9	.66	3.0	9	1.9	6.4	9	1.4	5.6			
1035	9	1.5	4.6	9	1.9	6.7	9	1.8	5.1			

Series B

	Field			0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
735	3	.20	6.9							9	.04	.22			
765	3	.44	1.5												
792	3	.97	2.0												
820	3	.76	1.7												
850	3	.13	.46												
890	3	.51	1.7												
925	3	2.1	.74				9	.16	.74						
950	3	11.1	10.5	9	.17	.71	9	.50	2.1	9	.01	.06			
980	3	9.6	11.7	9	.25	1.0	9	1.8	6.0	9	.06	.25			
1005	3	3.1	5.2				9	1.2	4.3	9	.07	.28			
1035	3	7.9	13.3	9	.79	4.5	9	.95	4.4	9	.16	.93			

time the experiment ended, the few laboratory plates on which *H. loosanoffi* had become established were experiencing increased coverage of this species.

Halichondria bowerbanki (Figure 13), an encrusting species, occurred frequently and with the greatest percent cover of any of the other sponges. *H. bowerbanki* first appeared on the 2°C and 4°C plates in the autumn of 1977. This species slowly increased its percent cover on 0°C, 2°C, and 4°C plates throughout the experiment reaching a maximum mean coverage in the laboratory of 18 percent on 2°C plates in Series "A" on the last sampling of the experiment. Series "A" and "B" plates had similar coverage by this species by the end of the experiment. As with *Haliclona loosanoffi* variability of percent cover by *H. bowerbanki* within a treatment was great. Percent cover of *H. bowerbanki* on 6°C plates was very low and its appearance was infrequent compared with other laboratory plates. This species first appeared on field plates in February 1979. It reached a peak mean abundance of 21.1 percent in July 1979 but then decreased to less than one percent in the autumn.

Leucosolenia canariensis (Table 12) and *Leucosolenia* sp. (Table 13) are small, erect, calcareous sponges which appeared frequently on laboratory plates but were never seen on field plates. The mean percent cover by these two species was low. The maximum mean cover of *L. canariensis* (4.9 percent) occurred in July 1979 (Day 925) on 6°C Series "B" plates. For *L.* sp. the maximum cover (4.3 percent) occurred in June 1979 on 0°C Series "B" plates. *L. canariensis* occurred on field plates and in all four temperature treatments while *L.* sp. was restricted mainly to the ambient (0°C) plates.

Coelenterata

Eudendrium ramosum, a hydroid, occurred only once and in very low abundance on laboratory 0°C plates (Table 14). On field plates this hydroid was seasonally important, occurring most frequently in the spring and autumn with maximum mean abundance of 10.5 percent cover in October 1979.

Pennaria tiarella (Table 15), a hydroid, occurred only once on a laboratory plate (6°C) and on five occasions on field plates where it had a maximum mean abundance of 8.2 percent cover in September 1979 (Day 980).

Aiptasia pallida, a small solitary anemone, occurred frequently on field and laboratory plates (Table 16). Its abundance on laboratory plates was extremely low: it never occurred with a mean abundance greater than 0.44 percent cover. In the field this anemone first appeared on plates in January 1979 (Day 735). On November 1979 (Day 1035), the last sampling date, it reached its maximum mean percent cover (47.2 percent) and was the single most dominant species on the field plates.

Astrangia danae (Table 17), an encrusting coral, occurred frequently but in low percent cover on field plates and in 0°C, 2°C and 4°C laboratory plates (Series "A"). On two occasions (November and December 1978) it occurred on a single field plate with cover of 11 and 15 percent; otherwise it was an insignificant member of the community.

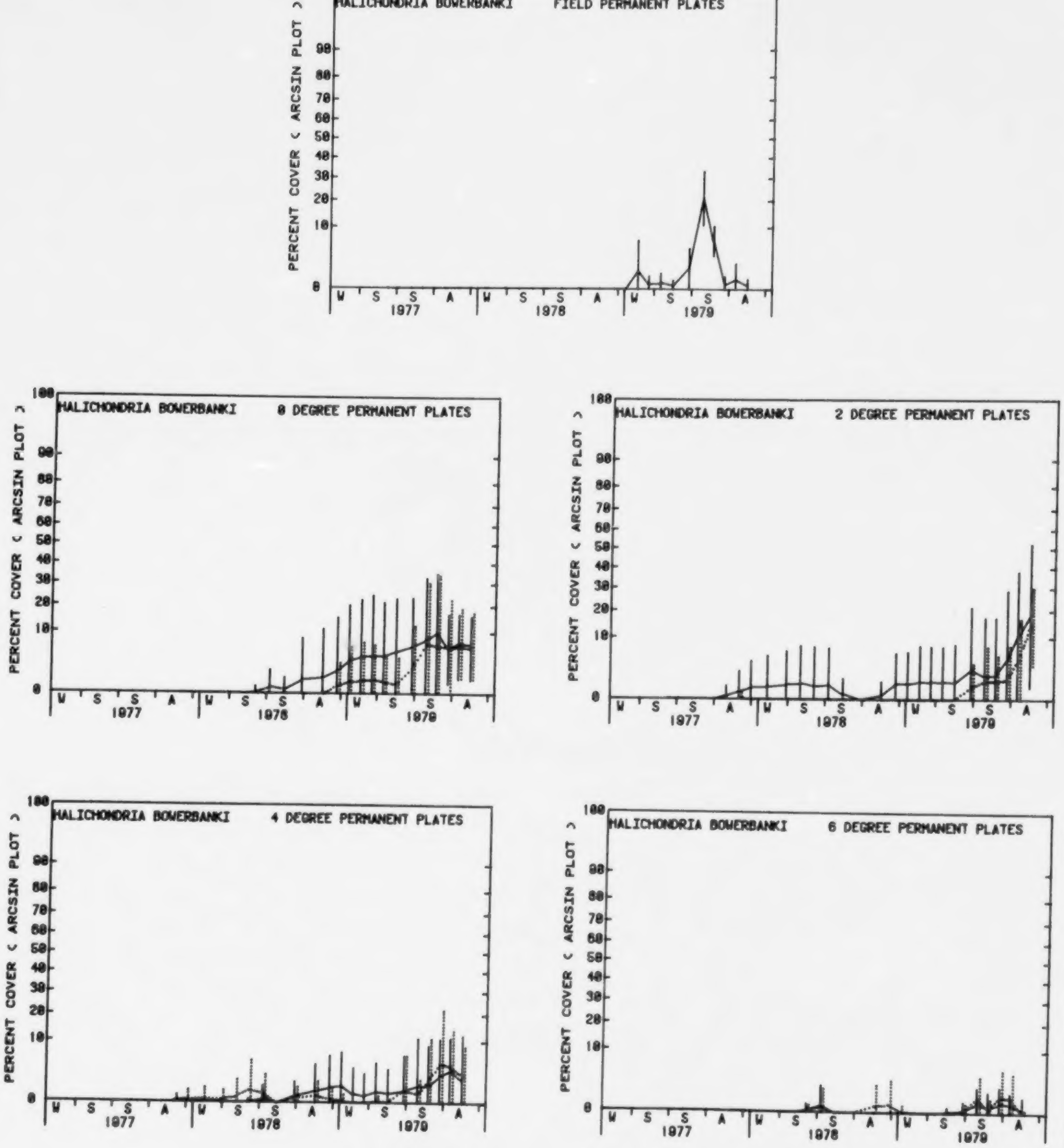

Figure 13. Mean (± SD) percent cover of the sponge, *Halichondria bowerbanki*, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 12. *LEUCOSOLENIA CANARIENSIS* PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
735										9	0.01	0.07
765										9	0.14	0.49
792										9	0.09	0.31
820										9	0.49	1.0
850	9	0.14	0.63							9	1.0	1.9
890	9	0.19	0.83	9	0.12	0.37	9	0.08	0.23	9	2.0	2.8
925	9	0.07	0.26	9	0.42	1.7	9	1.1	0.66	9	2.4	3.5
950	9	0.05	0.22	9	0.30	1.2	9	1.6	1.1	9	0.23	0.72
980	9	0.04	0.18				9	0.13	0.46			
1005							9	0.03	0.19			

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
735													9	0.02	0.13
765													9	0.12	0.50
792													9	0.44	1.1
820				9	0.01	0.07							9	1.1	2.7
850				9	0.44	1.3							8	0.63	1.5
890				9	0.40	0.93	9	0.42	1.1	9	0.06	0.27	8	2.9	2.9
925				9	0.06	0.14	9	1.1	3.1	9	0.45	1.3	8	4.9	3.5
950				9	0.03	0.12	9	0.64	1.9	9	0.19	0.64	8	0.37	1.0
980				9	0.04	0.16				9	0.13	0.52			
1005										0	0.05	0.19			

TABLE 13. LEUCOSOLENIA SP. PERCENT COVER

Series A

	0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
505	9	.05	.22									
540	9	.25	1.1									
620	9	.04	.27									
670	9	.14	.81									
705	9	.08	.49									
735	9	.08	.45									
765	9	.07	.43									
792	9	.07	.40									
820	9	.13	.55									
850	9	.34	.88									
890	9	1.3	1.8									
925	9	2.6	4.3	9	.12	.73						
950	9	1.2	2.5	9	.11	.56						
980	9	.57	1.0	9	.81	2.2						
1005	9	.14	.35	9	.57	1.8						
1035	9	.04	.18									

(continued)

TABLE 13 (continued)

Series B

	Field			0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
505				9	.15	.44									
540				9	.75	2.2									
575				9	.02	.11									
620				9	.01	.07									
670				9	.29	1.1				9	.02	.11			
705				9	.40	1.7				9	.02	.15			
735				9	.72	2.2									
765				9	2.1	6.3									
792				9	1.9	5.9									
820				9	1.2	3.8									
850				9	2.0	4.2									
890				9	4.3	6.2									
925				9	2.6	4.0									
950				9	1.7	2.6									
980				9	.91	1.9	9	.22	.72						
1005				9	.35	.85	9	.19	.63						
1035				9	.04	.11									

TABLE 14. EUDENDRIUM RAMOSUM PERCENT COVER

Series A

Day	0 Degree N	 Mean	 S.D.	2 Degree N	 Mean	 S.D.	4 Degree N	 Mean	 S.D.	6 Degree N	 Mean	 S.D.
820	9	.02	.10									

Series B

Day	Field N	 Mean	 S.D.	0 Degree N	 Mean	 S.D.	2 Degree N	 Mean	 S.D.	4 Degree N	 Mean	 S.D.	6 Degree N	 Mean	 S.D.
320	3	3.8	1.7												
348	3	1.5	3.3												
389	3	.79	2.7												
436	3	1.3	2.4												
470	3	6.3	2.9												
505	3	6.4	4.9												
540	3	2.3	3.8												
575	3	.13	.46												
620	3	.27	.92												
670	3	.69	1.2												
705	3	.25	.85												
735	3	.02	.08												
820	3	.19	.65	9	.02	.10									
850	3	.07	.23												
980	3	.21	.73												
1005	3	10.5	12.2												
1035	3	1.8	3.1												

TABLE 15. *PENNARIA TIARELLA* PERCENT COVER

Series A

Day	0 Degree N	0 Degree Mean	0 Degree S.D.	2 Degree N	2 Degree Mean	2 Degree S.D.	4 Degree N	4 Degree Mean	4 Degree S.D.	6 Degree N	6 Degree Mean	6 Degree S.D.
229										9	.02	.14

Series B

Day	Field N	Field Mean	Field S.D.	0 Degree N	0 Degree Mean	0 Degree S.D.	2 Degree N	2 Degree Mean	2 Degree S.D.	4 Degree N	4 Degree Mean	4 Degree S.D.	6 Degree N	6 Degree Mean	6 Degree S.D.
320	3	.97	.45												
620	3	.20	.69												
670	3	.09	.31												
980	3	8.2	13.3												
1005	3	4.1	7.0												

TABLE 16. AIPTASIA PALLIDA PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
260	9	.04	.18	9	.10	.31						
288	9	.02	.08	9	.05	.20						
320	9	.16	.67	9	.05	.20						
348	9	.17	.68									
389	9	.02	.15	9	.19	.78						
470				9	.07	.28						
505				9	.34	.87						
540	9	.02	.10	9	.14	.48						
575				9	.22	.75						
620				9	.14	.43						
670	9	.02	.10	9	.19	.57						
705				9	.12	.39						
735				9	.44	.71	9	.02	.13			
765	9	.02	.07	9	.22	.55						
792	9	.08	.24	9	.10	.33	9	.01	.07			
820	9	.08	.28	9	.20	.48				9	.03	.16
850	9	.03	.14	9	.19	.39	9	.01	.07	9	.03	.13
890				9	.15	.45				9	.03	.18
925				9	.04	.16	9	.04	.17	9	.02	.10
950				9	.12	.31	9	.06	.26			
980	9	.02	.10	9	.21	.51	9	.03	.12			
1005	9	.03	.13	9	.23	.50	9	.04	.13			
1035	9	.01	.07	9	.14	.41						

(continued)

TABLE 16 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
540				9	.03	.18	9	.04	.17						
575										9	.05	.19			
620										9	.03	.11			
735	3	14.6	16.5							9	.01	.07			
765	3	5.5	7.4				9	.03	.13	9	.01	.09			
792	3	11.3	8.4	9	.05	.19	9	.05	.19						
820	3	6.9	4.9	9	.06	.21	9	.04	.12	9	.02	.07			
850	3	7.7	8.1	9	.02	.13	9	.02	.14	9	.01	.07			
890	3	4.7	6.0												
925	3	10.9	4.1	9	.04	.15				9	.03	.14			
950	3	22.6	8.2	9	.06	.21				9	.14	.43			
980	3	26.2	15.5	9	.04	.16				9	.13	.45			
1005	3	42.8	17.7	9	.03	.14				9	.09	.34			
1035	3	47.2	9.5							9	.04	.17			

TABLE 17. ASTRANGIA DANAE PERCENT COVER

Series A

	0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
260	9	.09	.27	9	.05	.19						
288	9	.20	.51	9	.07	.27						
320	9	.23	.45	9	.05	.22						
348	9	.38	.74	9	.08	.30						
389	9	.21	.49	9	.02	.15						
436	9	.16	.43	9	.11	.42						
470	9	.46	1.1	9	.09	.37						
505	9	.62	1.2	9	.08	.33						
540	9	.49	.88	9	.19	.51						
575	9	.63	.97	9	.06	.22						
620	9	.92	1.2	9	.08	.23	9	.05	.19			
670	9	.72	.98	9	.05	.25	9	.05	.20			
705	9	.21	.50				9	.03	.12			
735	9	.18	.41				9	.03	.19			
765	9	.30	.52	9	.01	.07	9	.03	.16			
792	9	.15	.36	9	.03	.21	9	.01	.08			
820	9	.09	.22	9	.03	.16	9	.01	.07			
850	9	.15	.36	9	.02	.15						
890	9	.03	.12	9	.02	.15	9	.08	.25			
925	9	.20	.51	9	.02	.15	9	.07	.28			
950	9	.43	.80	9	.03	.21						
980	9	.22	.54									
1005	9	.14	.38									
1035	9	.20	.49									

(continued)

TABLE 17 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
348	3	.21	.73												
389	3	.22	.77												
436	3	.11	.39												
470	3	.02	.08												
620	3	1.0	3.5												
670	3	2.1	5.2												
705	3	2.2	4.1												
735	3	.65	1.6												
765	3	1.3	2.3												
792	3	1.2	2.4												
820	3	.26	.65												
850	3	.03	.12												

TABLE 18. *DIADUMENE LEUCOLENA* PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
202	9	.04	.18	9	.01	.07						
288	9	.08	.50	9	.27	.75						
320	9	.10	.40	9	.34	1.2						
348	9	.03	.14	9	.18	.72						
389	9	.02	.14	9	.20	.90	9	.02	.14			
436	9	.02	.15									
470	9	.02	.12	9	.39	1.2						
505	9	.06	.28	9	1.9	3.6	9	.04	.13			
540	9	.32	1.3	9	2.2	3.2	9	.13	.58			
575	9	.13	.56	9	.67	1.3	9	.35	1.2			
620				9	.27	.52	9	.10	.31			
670				9	.17	.42	9	.05	.29			
705				9	.21	.54	9	.02	.12			
735				9	.16	.49						
765				9	.17	.56	9	.02	.13			
792				9	.08	.29				9	.04	.15
820				9	.01	.05						
850							9	.01	.07			
925							9	.03	.20			

(continued)

TABLE 18 (continued)

Series B

	Field			0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
505				9	.02	.08									
575	3	.10	.35												
620	3	8.5	9.5												
670	3	20.1	20.9												
705	3	19.6	19.9												
735	3	2.1	2.2							9	.02	.07			
765	3	.63	1.1												
792	3	.04	.08												
890							9	.05	.32						

TABLE 19. *ANGUINELLA* *PALMATA* PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
145	9	.01	.08									
620	9	.12	.58									
670	9	.16	.47	9	.02	.14						
705	9	.06	.18	9	.03	.11	9	.23	1.0			
735	9	.52	1.1	9	.40	.94	9	.03	.11	9	.03	.17
765	9	1.0	2.2	9	.34	.99	9	.24	.54			
792	9	.59	.76	9	3.2	4.8	9	1.0	1.8			
820	9	4.4	3.2	9	6.8	5.1	9	2.3	3.1			
850	9	2.9	2.8	9	5.2	4.7	9	2.8	3.4			
890	9	.16	.50	7	.23	.80	9	.18	.42			
950	9	.01	.08									
980	9	.07	.21	9	.05	.32						
1005	9	.03	.12	9	.03	.21						
1035				9	.03	.14						

(continued)

TABLE 19 (continued)

Series B

Day	Field N	Field Mean	Field S.D.	0 Degree N	0 Degree Mean	0 Degree S.D.	2 Degree N	2 Degree Mean	2 Degree S.D.	4 Degree N	4 Degree Mean	4 Degree S.D.	6 Degree N	6 Degree Mean	6 Degree S.D.
670										9	.11	.53			
705							9	.46	2.1	9	1.7	3.2			
735				9	.23	.79	9	.35	.88	9	.54	1.6			
765				9	.73	2.3	9	.41	1.2	9	.34	1.1	9	.01	.07
792				9	.84	1.3	9	2.1	5.1	9	1.0	1.4	9	.04	.12
820	3	.19	.65	9	2.3	2.6	9	3.5	6.8	9	2.2	3.4	9	.05	.21
850	3	.07	.23	9	.81	1.7	9	1.8	3.5	9	1.5	3.1			
890				9	.04	.22	8	.11	.40	9	.05	.29			
925							9	.02	.14						
950				9	.05	.20	9	.02	.10						
980	3	.29	1.0	9	.26	.63									
1005	3	.44	.78	9	.14	.36	9	.02	.11						
1035	3	.01	.04												

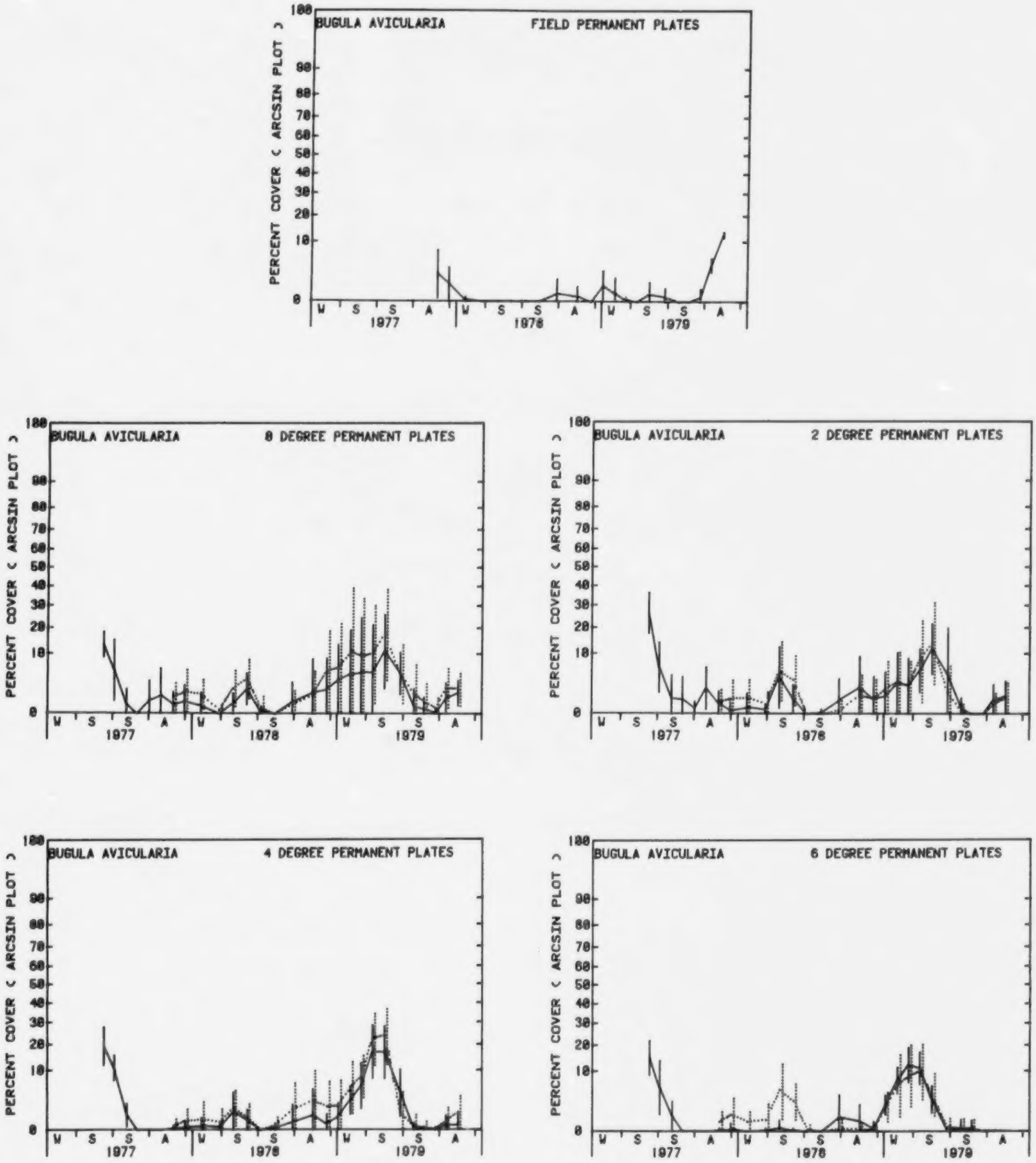

Figure 14. Mean (± SD) percent cover of the erect bryozoan, Bugula avicularia, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

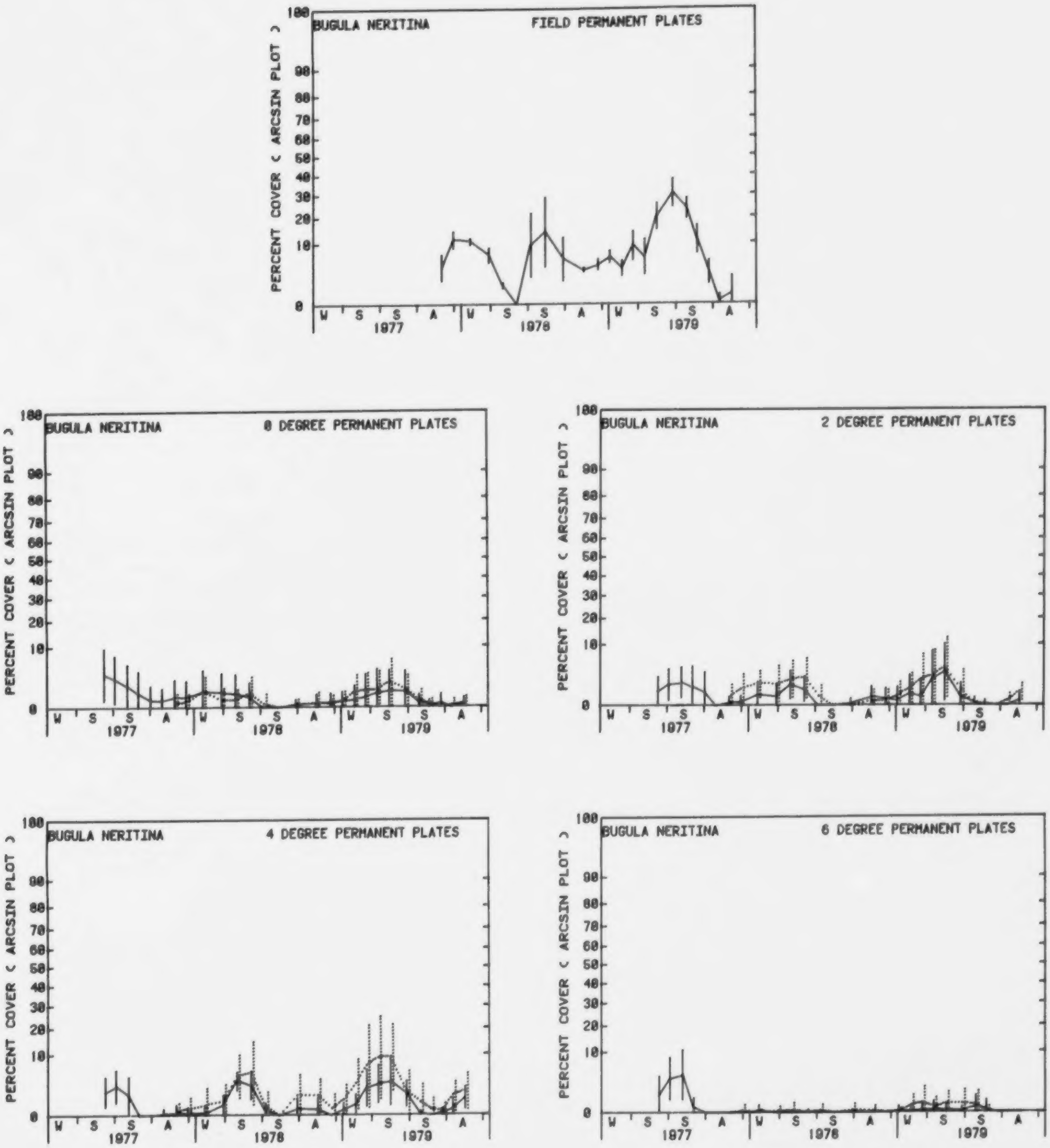

Figure 15. Mean (+ SD) percent cover of the erect bryozoan, Bugula neritina, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 20. SCHIZOPORELLA ERRATA PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
145	9	1.3	4.5	9	.78	2.4	9	.41	1.2			
170	9	1.4	4.6	9	.44	1.7	9	.22	.56	9	.02	.10
202	9	1.0	3.4	9	.43	1.3				9	.01	.07
229	9	.56	2.2									
260	9	.51	2.1	9	.02	.10						
288	9	.13	.64									
320	9	.06	.22									
348	9	.09	.43									
389	9	.14	.84									
436	9	.15	.89									
470	9	.23	1.1				9	.01	.07			
505	9	.37	1.3							9	.02	.14
540	9	.21	1.0							9	.01	.07
575	9	.09	.57									
765	9	.08	.26							9	.03	.20
792	9	.45	.81							9	.04	.22
820	9	.82	1.6							9	.03	.17
850	9	.59	1.4									
890	9	.05	.21									
925	9	.03	.18									
950	9	.04	.16									

(continued)

TABLE 20 (continued)

Series B

	Field			0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
320	3	79.9	12.5	9	.20	.48									
348	3	72.5	8.2												
389	3	61.4	15.2	9	.01	.07							9	.06	.32
436	3	69.5	14.7	9	.22	.38							9	.10	.35
470	3	54.3	24.6	9	5.2	8.6							9	.18	.58
505	3	41.3	25.6	9	3.4	7.4							9	.07	.36
540	3	22.4	25.9	9	3.9	7.7							9	.04	.17
575	3	25.5	38.9	9	1.1	3.6									
620	3	23.4	30.1	9	.25	.99									
670	3	36.4	13.1	9	.04	.22									
705	3	35.5	15.8	9	.04	.16									
735	3	25.0	24.7	9	.20	.64									
765	3	29.6	18.4	9	1.0	2.4							9	.02	.13
792	3	28.9	14.6	9	2.6	4.6									
820	3	19.7	14.2	9	3.4	5.7									
850	3	11.2	8.7	9	1.9	3.2				9	.05	.28			
890	3	6.0	8.0	9	.41	.88									
925	3	.97	2.3												
950	3	.02	.08	9	.03	.16									
980				9	.01	.07									
1005	3	.15	.50												
1035	3	.61	2.1												

Diadumene leucolena, a small solitary anemone, occurred in large numbers on the field plates in the autumn and early winter of 1978 (Days 670 and 705) with a maximum mean percent cover of 20.1 percent (Table 18). This species also occurred frequently on laboratory Series "A" plates at 0°C, 2°C and 4°C, but only twice on Series "B" plates and once on 6°C Series "A" plates. *D. leucolena* had very low mean percent coverage on laboratory plates (maximum 2.2 percent).

Bryozoa

Anguinella palmata, an erect bryozoan, occurred frequently on laboratory plates at 0°C, 2°C, and 4°C, but only four times at 6°C (Table 19). Maximum mean abundance of *A. plamata* was 6.8 percent cover at 2°C, Series "A" in March 1979 (Day 820). On field plates this species occurred on five occasions with a maximum mean abundance of 0.4 percent cover.

Bugula avicularia, an erect bryozoan, occurred very frequently on the field and laboratory plates (Figure 14). Its abundance on field plates was generally quite low except for the last sampling (November 1979) when it reached a maximum mean abundance of 12.5 percent cover. In the laboratory *B. avicularia* appeared almost continuously throughout the three years of the project with very little difference among the temperature treatments. In general it was a spring and fall species with minimum percent cover occurring during middle to late summer. It reached a maximum mean abundance (approximately 25 percent) on the 2°C plates in May 1977 (the first sampling). There was no significant difference between the Series "A" and "B" plates except for a greater abundance on Series "B" at 6°C in the winter and spring of 1978.

Bugula neritina, an erect bryozoan, occurred very frequently on field and laboratory plates (Figure 15). It differed from *B. avicularia* in having its greatest abundance on field plates and significantly lower abundance on laboratory plates. In the field variations in abundance could not be correlated with season, although its maximum mean abundance (30.9 percent cover) occurred in June 1979. Maximum abundances on the laboratory plates usually occurred in the spring. This species occurred with much less frequency and much less abundance on the 6°C laboratory plates than on plates at other temperatures. There was no significant difference in its abundance between Series "A" and "B."

Schizoporella errata, an encrusting bryozoan, occurred frequently on field and laboratory 0°C plates but with very low frequency on the other laboratory plates (Table 20). On the 0°C laboratory plates maximum mean abundance was 5.2 percent cover and it was seldom a significant member of the community. On the field plates *S. errata* was the dominant member of the community (79.9 percent cover) at the first sampling for field plates (October 1977); however, dominance decreased continuously throughout the experiment until at the last sampling its mean abundance was only 0.6 percent cover.

Annelida

Hydroides dianthus, a moderate-sized serpulid polychaete, occurred frequently on both field and laboratory plates (Figure 16). It occurred with a low but fairly constant mean percent cover for all treatments. The Series "B" plates at 0°C, 2°C and 4°C had a slightly higher percent cover in 1978 than the Series "A" or field plates. *H. dianthus* appeared to be little influenced by the experimental system (compare field with laboratory 0°C plates) or temperatures within the system. This species showed no seasonal or annual cycles in abundance.

Sabellaria vulgaris, a Sabellid polychaete of approximately the same size as *H. dianthus*, occurred frequently on the laboratory plates in all treatments but infrequently on field plates (Table 21). Maximum mean percent cover was usually less than one percent and this species was never an important (in percent cover) member of the community.

Spirorbis borealis, a tiny serpulid polychaete, was never counted on field plates yet it was extremely important on laboratory plates where it occurred during every sampling period (Figure 17). The greatest percent cover by *S. borealis* was on the 2°C and 4°C plates with a maximum mean percent cover of 75.2 percent in January 1978 on the Series "B" plates at 4°C. Its abundance on 0°C plates was somewhat less than that on the 2°C and 4°C plates. At 6°C percent cover was less than at 0°C. *S. borealis* has a very brief, free-swimming larval stage (from 15 min to two hours), thus its high percent cover was undoubtedly maintained by recruitment from within the laboratory system. No seasonal or annual patterns were observed in the percent cover data. The decrease in abundance from 1978 to 1979 (at 0°C, 2°C, and 4°C) may have been due to increased frequency of cleaning of the experimental tanks in 1979, which reduced the population available to produce new recruits for the plates. *S. borealis* were frequently counted as epipoints on laboratory plates which often made the total percent cover by all species greater than 100 percent. In late 1977 and early 1978 there was greater percent cover by *S. borealis* on Series "B" than on Series "A" plates at 4°C. Otherwise Series "A" and "B" had the same percent cover.

Mollusca

Argopecten irradians, the bay scallop, occurred only once on one plate with abundance greater than 10 percent cover (Table 22). In general, *A. irradians* occurred with low to moderate frequency on field and laboratory plates, with a maximum mean abundance of 0.3 percent cover. Thus, *A. irradians* was never a significant member of the community in terms of percent cover.

Crassostrea virginica, the common eastern oyster, was the single most important member of the community on the laboratory plates (Figure 18). Oysters quickly occupied most of the primary space available on all laboratory plates in all treatments, then remained at a more or less constant 60 to 70 percent cover except at 6°C. On 6°C plates there was a dramatic decrease in percent cover in the late summer of 1978 and a lesser decrease in the late

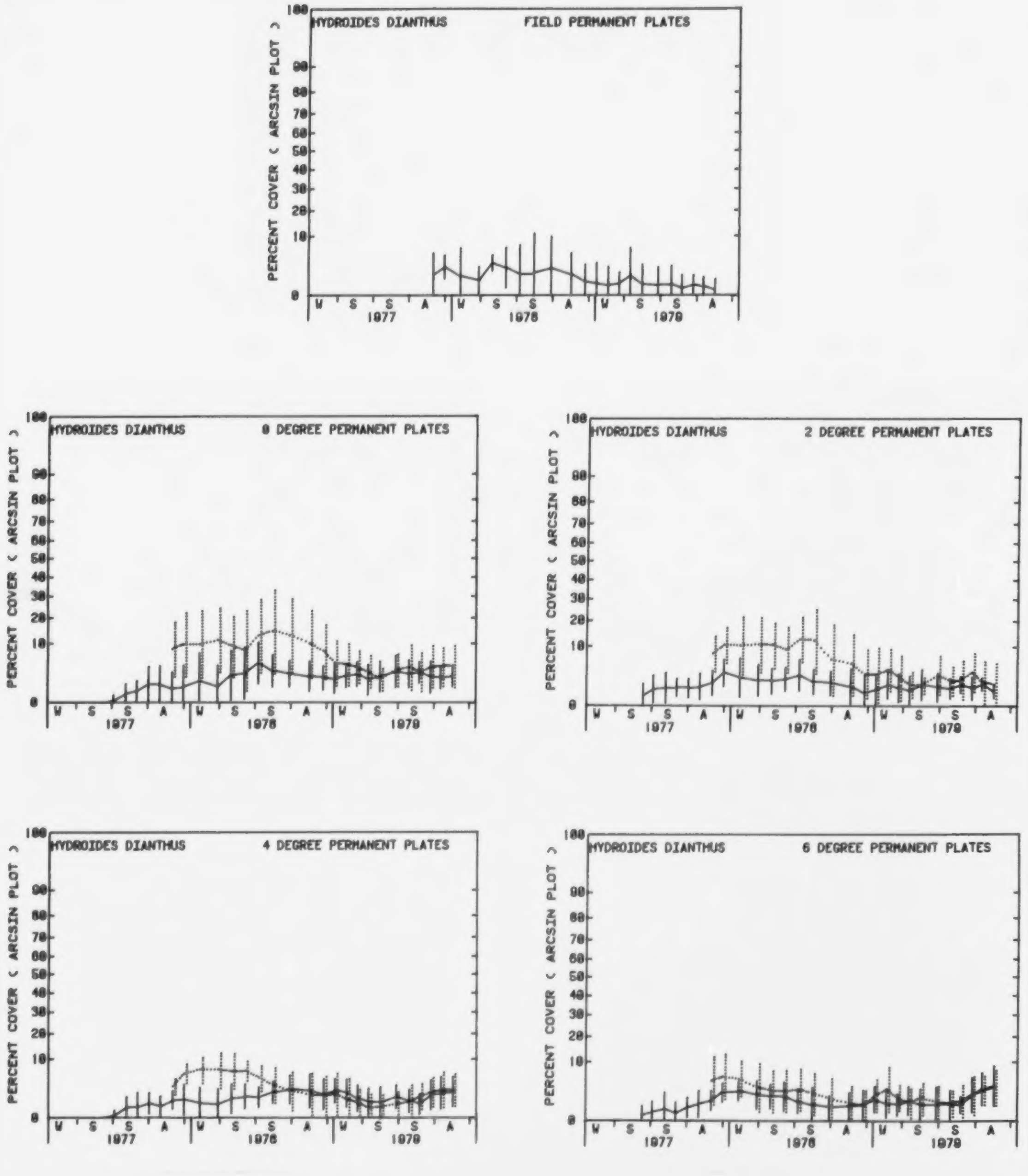

Figure 16. Mean (+ SD) percent cover of the polychaete, Hydroides dianthus, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 21. SABELLARIA VULGARIS PERCENT COVER

Series A

	0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
145				9	.03	.11						
170	9	.30	.55	9	.80	1.4	9	.61	.81	9	.36	.48
202	9	1.8	1.8	9	2.9	1.3	9	1.6	1.2	9	1.4	2.0
229	9	.72	1.2	9	.58	1.2	9	.88	1.4	9	.73	1.3
260	9	.79	1.3	9	.44	1.1	9	.20	.60	9	.05	.32
288	9	.67	1.1	9	.08	.31	9	.04	.21			
320	9	.31	.74	9	.06	.21	9	.10	.31			
348	9	.22	.60	9	.13	.54	9	.05	.21			
389	9	.09	.33	9	.22	.88	9	.06	.38			
436	9	.28	.76	9	.71	1.1	9	.05	.18			
470	9	.18	.51	9	.22	.49	9	.05	.25			
505	9	.20	.63	9	.07	.31						
540	9	.28	.91	9	.05	.19						
575	9	.07	.29	9	.02	.11						
735				9	.01	.09				9	.13	.41
765				9	.11	.35	9	.01	.07	9	.21	.67
792	9	.06	.23	9	.17	.42	9	.01	.07	9	.08	.34
820	9	.04	.26	9	.15	.38				9	.06	.22
850										9	.03	.13
890	9	.21	.51									
925	9	.10	.28									
950										9	.02	.10
980				9	.03	.14				9	.02	.10
1035							9	.22	.75			

(continued)

TABLE 21 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
320				9	.11	.26	9	.04	.15						
348				9	.02	.10				9	.01	.07			
389							9	.14	.58						
436				9	.39	.65	9	.29	.81	9	.12	.48			
470				9	.57	1.2	9	.10	.36	9	.06	.27			
505				9	.23	.61	9	.07	.40						
540				9	.36	1.1	9	.03	.19						
575				9	.04	.22									
735							9	.07	.22	9	.06	.21	9	.03	.14
765				9	.12	.30	9	.06	.26	9	.06	.19	9	.02	.10
792	3	.21	.73	9	.17	.46	9	.23	.73	9	.21	.50	9	.13	.39
820	3	.03	.12	9	.09	.22	9	.06	.20	9	.12	.36	9	.14	.39
850				9	.18	.44							8	.01	.07
890	3	.21	.73	9	.36	.83	9	.18	.58	9	.02	.10	8	.07	.20
925	3	.08	.27	9	.24	.59	9	.02	.06				8	.08	.23
950				9	.04	.16									
980				9	.02	.10									
1035										9	.03	.13			

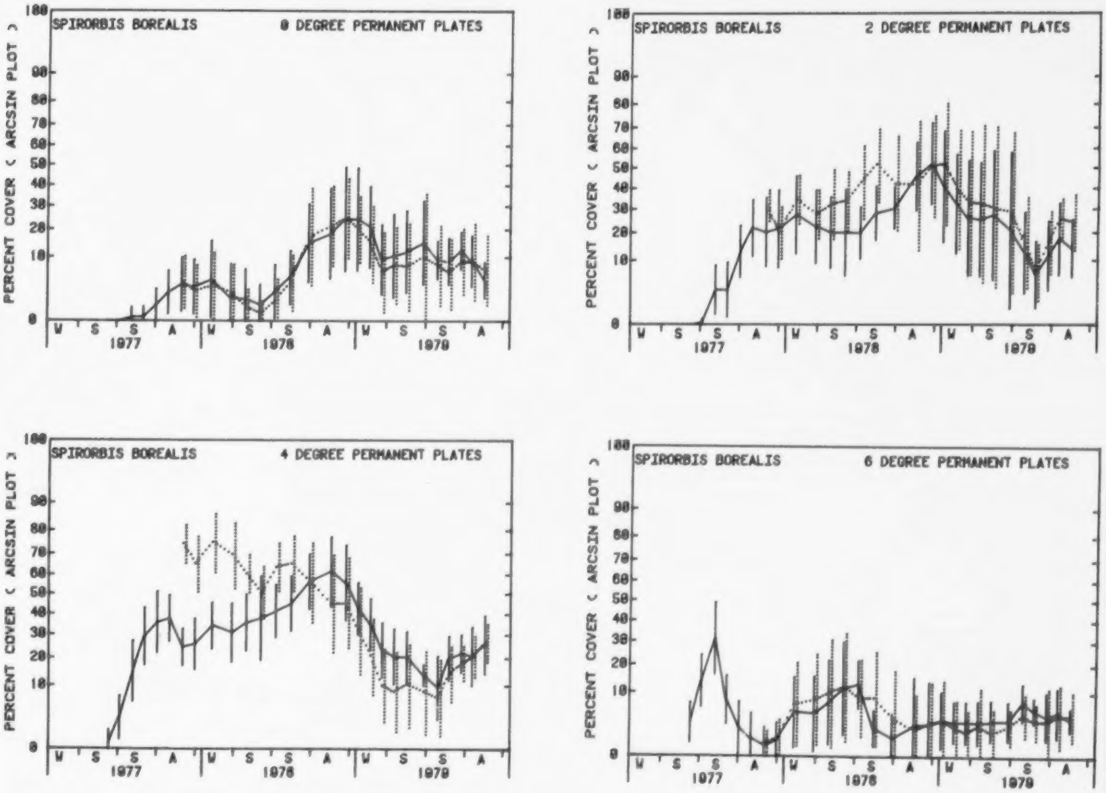

Figure 17. Mean (± SD) percent cover of the polychaete, *Spirorbis borealis*, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 22. ARGOPECTEN IRRADIANS PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
170	9	.04	.14				9	.03	.10			
202	9	.06	.21				9	.02	.10			
229							9	.14	.58			
260				9	.13	.56						
288				9	.13	.41						
320				9	.03	.13						
348				9	.08	.35						
389				9	.09	.38				9	.06	.38
436										9	.31	.89
470	9	.04	.17							9	.24	.77
705							9	.01	.06	9	.03	.16
735							9	.07	.27	9	.04	.22
765							9	.02	.09	9	.01	.09
792							9	.04	.15	9	.02	.09
820							9	.13	.46			
850				9	.04	.27	9	.13	.58			
890				8	.04	.21						
950				9	.05	.28	9	.01	.06			
980							9	.06	.25			
1005				9	.02	.11						

(continued)

TABLE 22 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
320													9	.01	.07
348													9	.02	.10
389													9	.05	.21
436													9	.12	.40
470													9	.12	.49
505													9	.08	.38
670							9	.02	.13						
705							9	.08	.40	9	.02	.10			
735	3	.10	.35				9	.12	.38	9	.04	.22			
765										9	.04	.25			
792										9	.06	.33	9	.03	.14
820													9	.06	.25
850													8	.05	.29
890	3	.08	.27				9	.03	.18						
925	3	.20	.69	9	.01	.08	9	.01	.05						
950	3	.06	.19	9	.18	.49	9	.14	.42						
980				9	.24	.64	9	.25	.61						
1005				9	.17	.54	9	.02	.10						
1035	3	.10	.35	9	.04	.15									

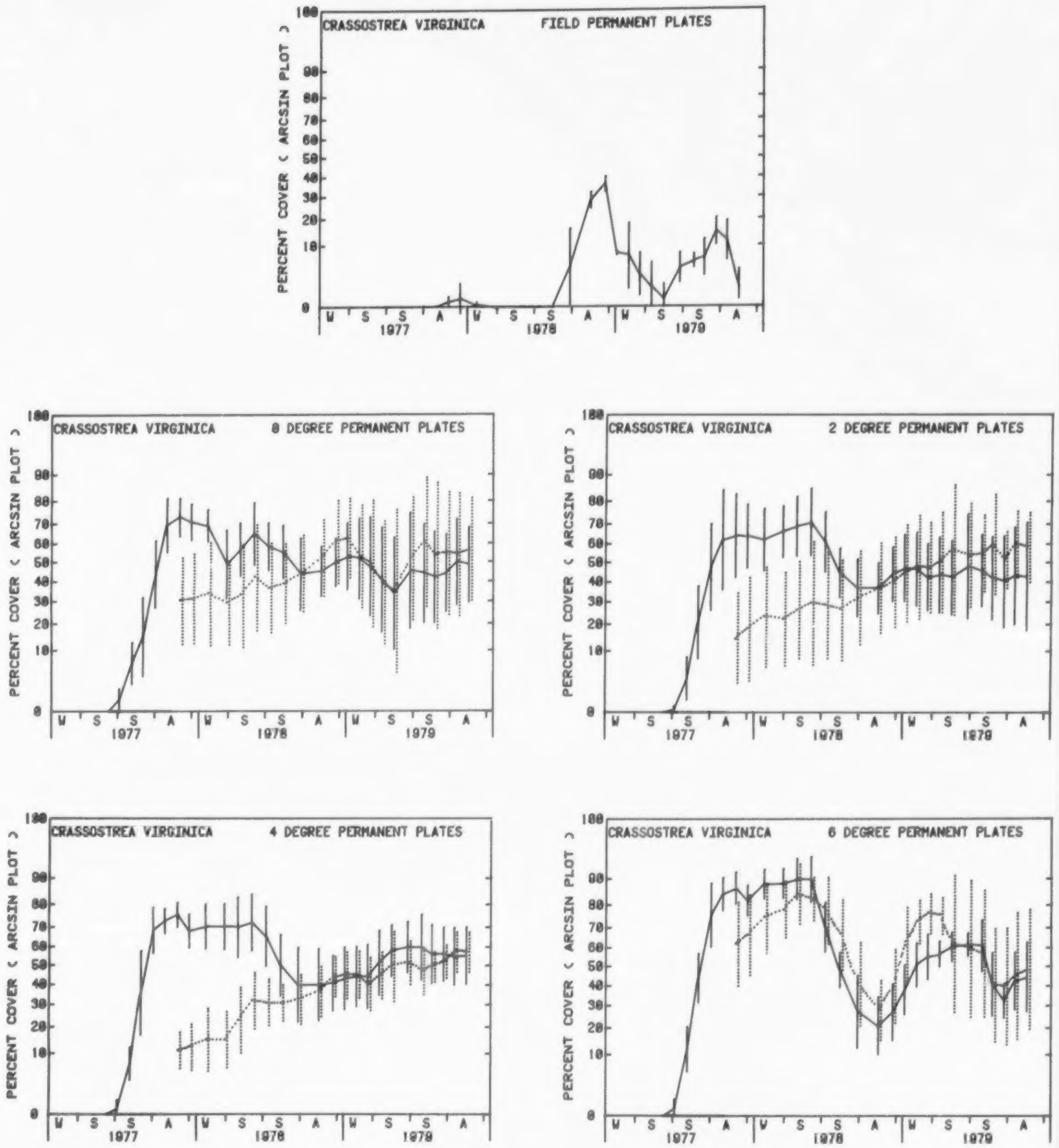

Figure 18. Mean (± SD) percent cover of the oyster, Crassostrea virginica, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

summer of 1979. This decrease was caused by the death of the large oyster community as the water temperatures reached their annual maximum. Percent cover by oysters at 2°C and 4°C decreased slightly in 1978 but not in 1979. C. virginica did not occur in such great abundance on field plates. This species usually is excluded from subtidal habitats in the vicinity of the Duke Laboratory dock (from which field plates were suspended) due to predation by oyster drills. Oyster drills pass through their larval stages in a capsule and hatch as immature adults. Probably for this reason oyster drills were excluded from the laboratory system. Except for 6°C plates, the Series "B" plates had lower percent cover in 1978 than Series "A." In 1979 percent cover was similar for both series.

Geukensia demissa, the Atlantic ribbed mussel, occurred frequently on the laboratory plates but was counted on only five occasions on field plates (Figure 19). This species occurred with much greater frequency on Series "A" than on Series "B" plates. It appeared that recruitment was heavy in the summer of 1977 on "A" plates (before the start of the Series "B" experiment) and that most of the animals on the Series "A" plates during 1978 and 1979 were the result of that initial recruitment. There was little or no significant difference among the four laboratory treatments throughout the experiment, although the percent cover on the 0°C Series "A" plates was greatest (maximum mean abundance of 9.7 percent). No seasonal or annual patterns were observed in the percent cover data.

Modiolus americanus, the tulip mussel, occurred frequently on laboratory Series "A" 0°C, 2°C, and 4°C plates (Table 23). It never occurred on field plates and occurred only once on 6°C plates. M. americanus occurred in very low abundance with its maximum mean percent cover of 2.2 percent occurring on 0°C Series "A" plates in July 1978 (Day 575).

Arthropoda

Balanus spp., a mixed assemblage of several unidentified species of barnacles, occurred frequently on field and laboratory plates (Table 24). At the beginning of the respective experiments barnacles occupied significant space on plates in the field (mean of 25 percent cover) and the laboratory Series "A" plates (mean at 0°C of 7.6 percent; 2°C of 12.4 percent; 4°C of 11.8 percent; 6°C of 10.7 percent). Percent cover decreased rapidly in the laboratory so that from August 1977 to the end of the experiment barnacles generally had less than one percent cover. In the field the percent cover by barnacles exhibited a seasonal cycle with a maximum of 10 - 20 percent occurring in spring and autumn and a minimum of less than one percent in winter and summer.

Corophium acherusicum, a small tube-dwelling amphipod, occurred during every sampling period in the laboratory system but only on five occasions, with very low abundance, in the field (Figure 20). The pattern of occurrence on Series "A" and Series "B" plates was similar. At 0°C the mean abundance at the first sampling period was 10 percent cover. Coverage increased until April 1978 when a maximum mean abundance of 36.4 percent cover was recorded. During the summer and autumn of 1978 the number dropped to zero percent or

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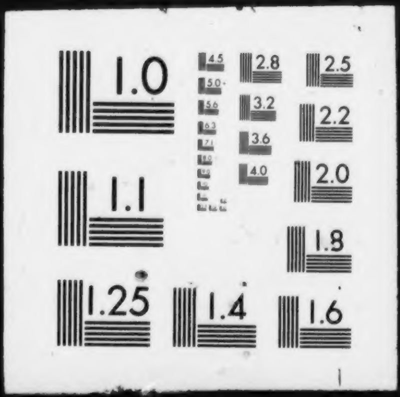
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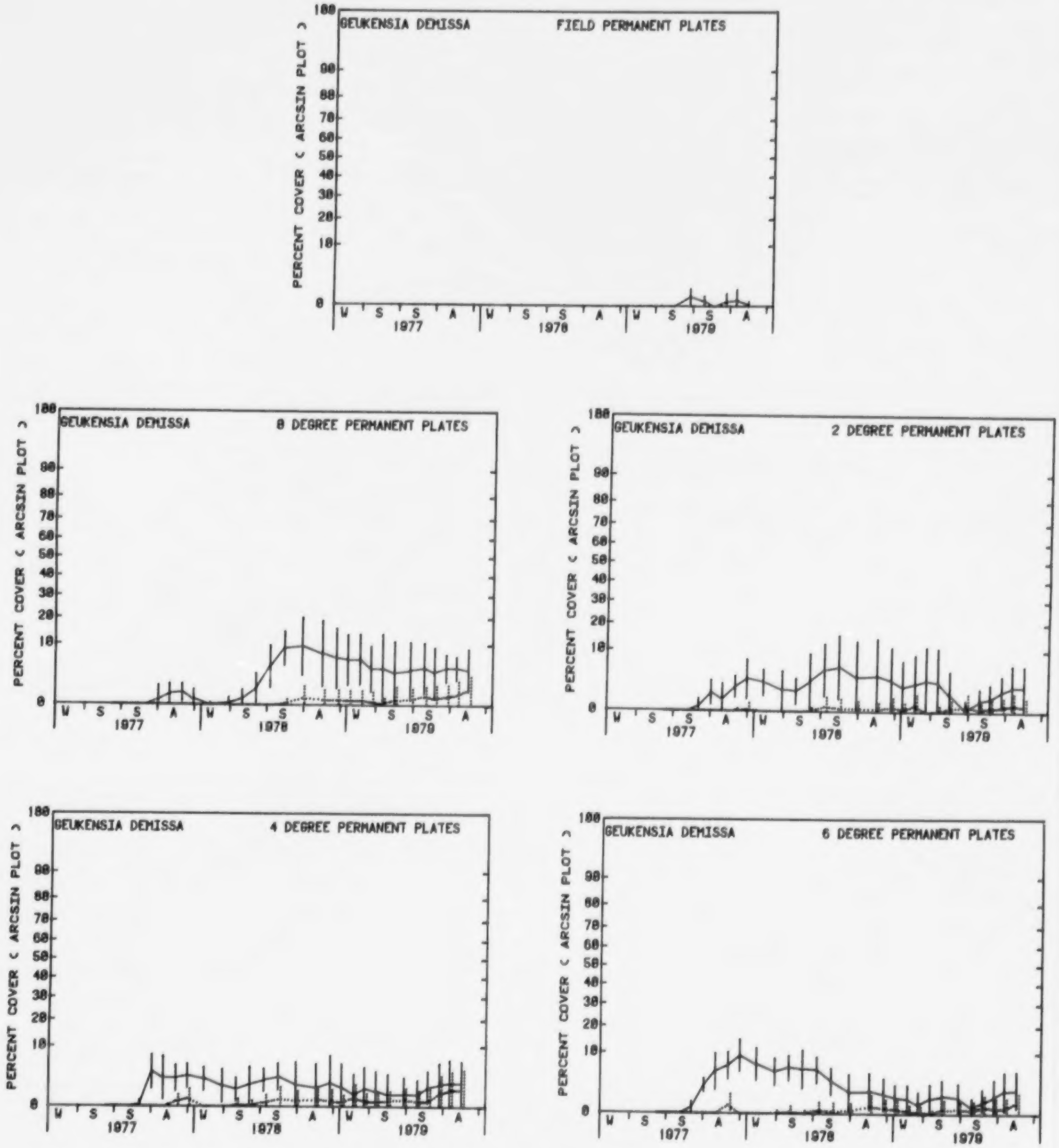

Figure 19. Mean (± SD) percent cover of the mussel, *Geukensia demissa*, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 23. *MODIOLUS AMERICANUS* PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
288							9	.08	.28			
320	9	.07	.23	9	.15	.52	9	.30	.61			
348	9	.17	.45	9	.56	1.5	9	.28	.77			
389	9	.15	.52	9	.43	1.5	9	.29	.71			
436	9	.07	.29	9	.27	.77	9	.41	1.2			
470	9	.24	.57	9	.07	.31	9	.14	.46			
505	9	.65	1.2	9	.24	.61	9	.24	.62			
540	9	.99	2.1	9	.81	1.8	9	.08	.29			
575	9	2.2	3.3	9	1.8	3.1						
620	9	1.9	3.5	9	.21	.83	9	.06	.24			
670	9	1.2	2.8	9	.49	1.5	9	.23	.73			
705	9	.59	2.1	9	.42	1.5	9	.11	.47			
735	9	.40	1.3	9	.61	1.8	9	.11	.51			
765	9	.26	.69	9	.14	.51	9	.12	.55			
792	9	.24	.58	9	.07	.44	9	.05	.31			
820	9	.02	.13	9	.12	.71	9	.07	.39			
850	9	.05	.21	9	.03	.21	9	.05	.23			
890	9	.39	1.1	9	.01	.09	9	.23	.75			
925	9	1.5	3.8				9	.10	.45			
950	9	1.2	2.7	9	.38	1.2	9	.05	.19			
980	9	1.5	3.2	9	.46	.80	9	.25	.85			
1005	9	1.2	2.3	9	.39	.72	9	.39	1.2			
1035	9	1.4	3.0	9	.44	.91	9	.12	.52			

(continued)

TABLE 23 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
505													9	.01	.07
735										9	.09	.35			
765										9	.03	.18			
850										9	.05	.28			
925				9	.02	.10									
950				9	.04	.26									
980				9	.07	.27	9	.01	.09						
1005				9	.14	.45	9	.01	.08	9	.03	.21			
1035				9	.12	.35				9	.03	.17			

TABLE 24. BALANUS SPP. PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
145	9	7.6	4.1	9	12.4	4.7	9	11.8	4.2	9	10.7	4.9
170	9	5.9	4.2	9	9.7	6.3	9	8.1	2.1	9	5.9	3.7
202	9	3.2	2.1	9	8.3	5.4	9	5.8	3.7	9	3.1	2.2
229	9	.65	.67	9	.07	.23	9	.65	.86	9	.65	1.0
260	9	.64	1.4	9	.05	.18	9	.31	.57	9	.34	.73
288	9	.04	.19	9	.03	.12	9	.05	.17	9	.02	.09
320	9	.03	.11									
348	9	.02	.15	9	.02	.13						
389	9	.01	.07	9	.01	.07	9	.02	.14			
436	9	.06	.16	9	.01	.03						
470	9	2.2	2.2	9	.07	.28				9	.09	.31
505	9	.82	1.3				9	.07	.26	9	.10	.31
540	9	.56	.97	9	.01	.07	9	.04	.17			
575	9	.18	.45				9	.02	.09			
620							9	.01	.07			
765							9	.01	.07			
792				9	.17	.52				9	.03	.11
820	9	.08	.25	9	.06	.22				9	.12	.31
850	9	.06	.22							9	.07	.27
890				9	.01	.07						
950	9	.05	.20									
980	9	.02	.10				9	.01	.07	9	.04	.16
1005										9	.06	.19
1035										9	.05	.21

(continued)

TABLE 24 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
320	3	25.0	3.1	9	.08	.24									
348	3	10.1	3.6							9	.01	.07			
389	3	3.3	.75	9	.01	.07									
436	3	1.4	2.3	9	.21	.31									
470	3	.33	.73	9	2.6	1.3				9	.02	.10	9	.07	.23
505	3	18.7	11.5	9	.58	.66							9	.21	.61
540	3	3.2	2.0	9	1.2	1.1				9	.09	.26	9	.51	3.0
575	3	.10	.35	9	.39	.85	9	.07	.21						
620	3	4.9	1.2	9	.06	.23									
670	3	2.0	.48												
705										9	.02	.09			
735	3	2.6	.86							9	.39	.83			
765	3	6.3	3.5							9	.09	.26	9	.01	.07
792	3	12.2	5.8	9	.01	.06	9	.17	.39				9	.06	.2
820	3	12.6	5.6	9	.16	.33	9	.30	.70	9	.04	.17	9	.07	.22
850	3	4.6	3.7	9	.14	.34							8	.07	.20
890	3	.50	1.7	9	.02	.10							8	.03	.12
925	3	.11	.39	9	.03	.13									
950				9	.04	.18									
980							9	.03	.12				8	.01	.06
1005							9	.04	.13				8	.02	.09
1035	3	.10	.35										8	.03	.11

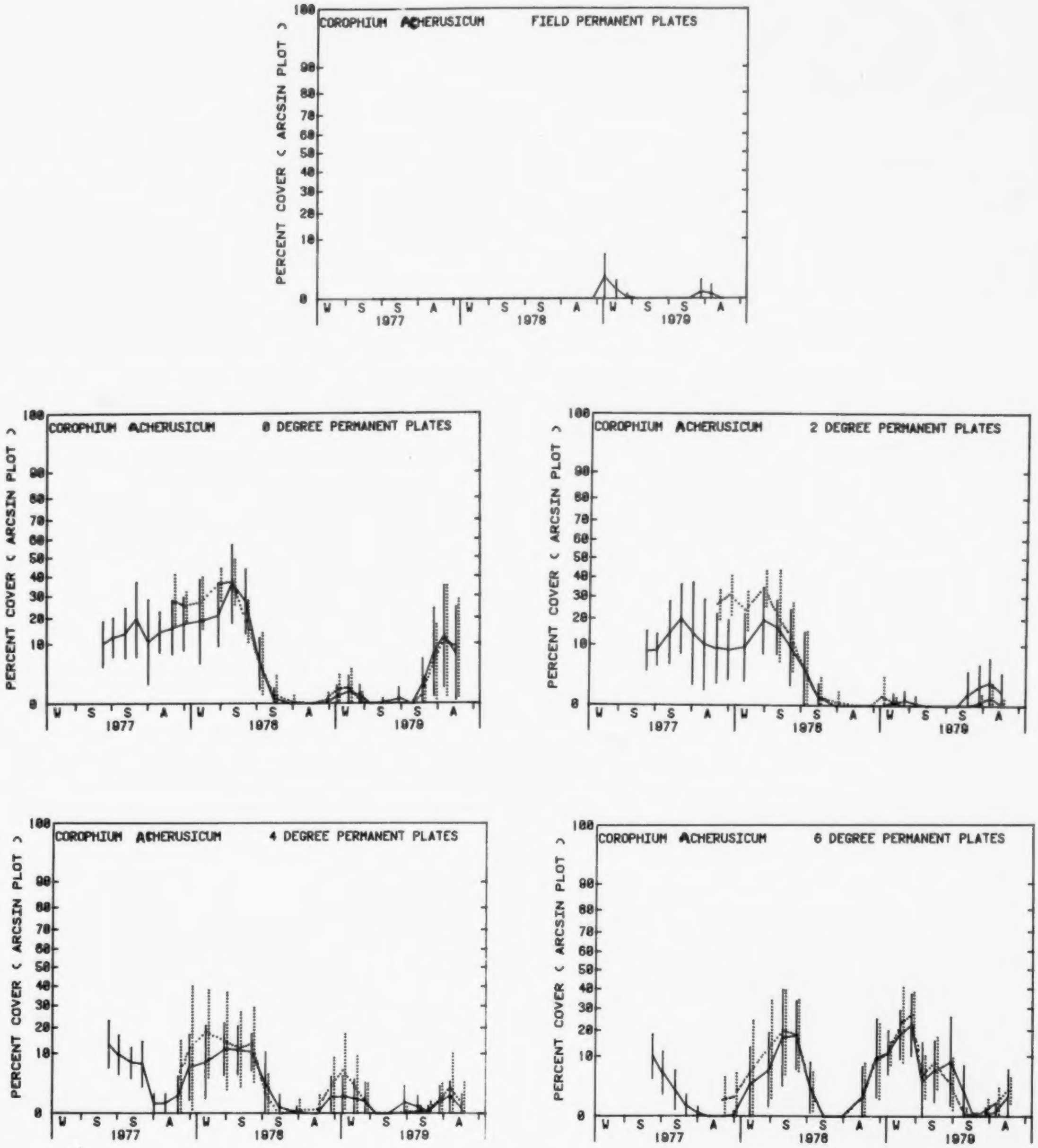

Figure 20. Mean (+ SD) percent cover of the amphipod, Corophium acherusicum, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

near zero percent but increased again in autumn 1979 to 12.4 percent cover. The pattern at 2°C was similar except that recovery in autumn 1979 was much less pronounced. At 4°C and 6°C there was an annual cycle in percent cover, probably as a result of elevated water temperatures, with zero percent or near zero percent cover in late summer when temperatures were the highest; during cooler seasons there was an increase in the population during cooler seasons with a maximum percent cover occurring in the winter and spring. C. acherusicum broods its young and thus most recruitment probably occurred from populations within the laboratory system. The large numbers which occurred on plates during 1977 to 1978 could have come from recruitment from sides and bottoms of the experimental tanks which were infrequently cleaned. Regular cleaning in 1979 could have caused the reduced population in the 0°C, 2°C, and 4°C tanks; however, in the 6°C tanks populations were approximately the same for these two periods. C. acherusicum could be seen attached to the surfaces of most of the other species in the communities. They were frequently counted as epipoints since their mud tubes did not appear to require primary space for attachment. The low occurrence of C. acherusicum on field plates may have been due to the predatory activities of fish, shrimp, and swimming crabs which were present around the field plates but which did not occur in the laboratory tanks.

Urochordata

Ascidia interrupta, a large solitary tunicate, occurred frequently on both field and laboratory plates (Figure 21). In the field the maximum mean abundance of 8 percent cover occurred in August 1979. Except for the summer of 1979 abundance was less than one percent on the field plates. In the laboratory A. interrupta had a greater frequency of occurrence and was generally more abundant at 0°C and 2°C than at 4°C and 6°C. Maximum mean abundance of 9.3 percent cover occurred in October 1979 on the 2°C Series "B" plates.

Botryllus schlosseri, an encrusting colonial tunicate, occurred frequently in the laboratory but was recorded only twice on field plates (Table 25). In the laboratory B. schlosseri occurred more frequently and in greater abundance at 0°C than at the other treatment temperatures. A maximum mean abundance of 4.9 percent cover was recorded in June, 1978 on the 0°C, Series "B" plates.

Molgula manhattensis, a moderate-sized solitary tunicate, occurred infrequently on field plates but seasonally with maxima in the late spring on the laboratory plates (Figure 22). In the laboratory its pattern of appearance was similar on the Series "A" and Series "B" plates. Except for the initial sampling periods, its abundance decreased as the temperature in the laboratory increased. Maximum mean abundance of 21.7 percent cover occurred in March 1979 on 0°C Series "B" plates.

Perophora viridis, a small solitary tunicate, occurred frequently on laboratory plates and infrequently on field plates (Figure 23). P. viridis was strongly seasonal in occurrence with maximum cover occurring in the late spring and summer. In the laboratory, Series "A" and "B" were similar in

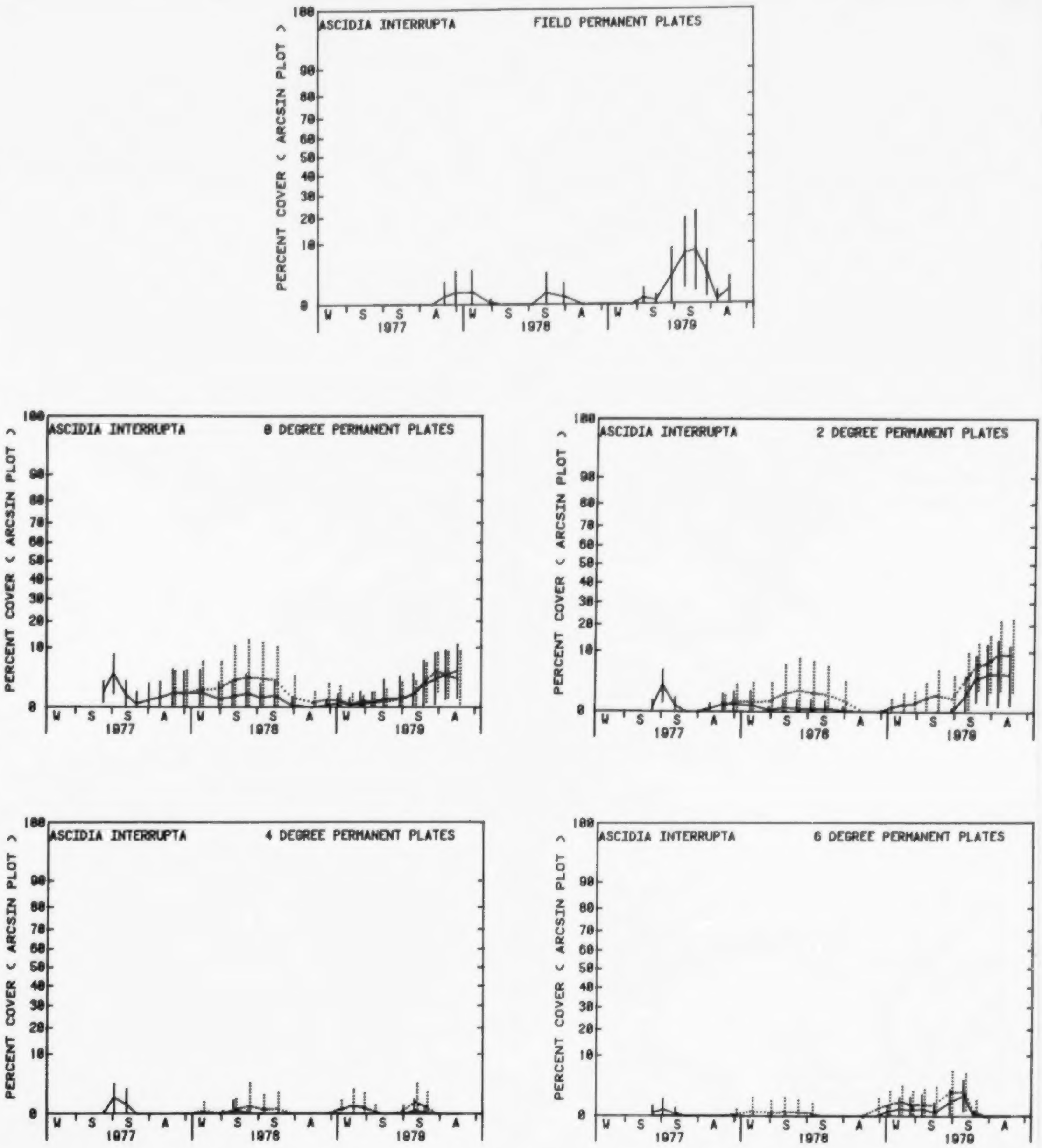

Figure 21. Mean (± SD) percent cover of the tunicate, Ascidia interrupta, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 25. BOTRYLLUS SCHLOSSERI PERCENT COVER

Series A

	0 Degree			2 Degree			4 Degree			6 Degree		
Day	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
145	9	1.9	5.8	9	.05	.29	9	.09	.51			
170	9	4.2	12.3	9	1.4	5.7	9	.22	1.3			
202	9	.14	.64	9	.15	.62	9	.19	1.1			
260	9	.13	.76									
288	9	.58	3.4									
320	9	.99	5.6									
348	9	1.8	8.3									
389	9	2.1	7.9									
470	9	.08	.47	9	.17	1.0	9	.04	.25	9	.48	2.2
505	9	.63	3.0	9	.39	2.3	9	.83	4.2	9	.59	3.1
540	9	2.0	6.9	9	.78	4.5	9	1.1	4.5	9	.10	.60
575	9	2.2	7.5	9	.36	2.1						
620										9	.27	1.6
670										9	2.6	9.6
705										9	.85	3.3
765							9	.09	.55			
792							9	.15	.86			
850	9	.01	.07									
890	9	.03	.16									
1005	9	.09	.55	9	.01	.08				9	.10	.33
1035	9	.30	1.8	9	.07	.39	9	.06	.34	9	.23	.74

(continued)

TABLE 25 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
320				9	.09	.54									
348				9	.81	2.9									
389	3	.64	2.2	9	2.9	8.5									
436	3	.01	.04												
470				9	.30	1.2									
505				9	2.3	7.2	9	.06	.33						
540				9	4.9	13.4	9	.24	1.4						
575				9	3.5	10.2	9	.03	.19						
620				9	.30	1.8							9	.24	1.4
670				9	.83	4.7							9	3.0	9.2
705													9	1.5	4.6
735													9	.17	.54
820				9	.01	.07									
850				9	.92	2.9									
890				9	2.3	6.4									
925				9	.06	.38				9	.04	.22			
950				9	.03	.20				9	.02	.13			
980				9	.03	.16									
1005													8	.03	.19
1035				9	.10	.41							8	.08	.46

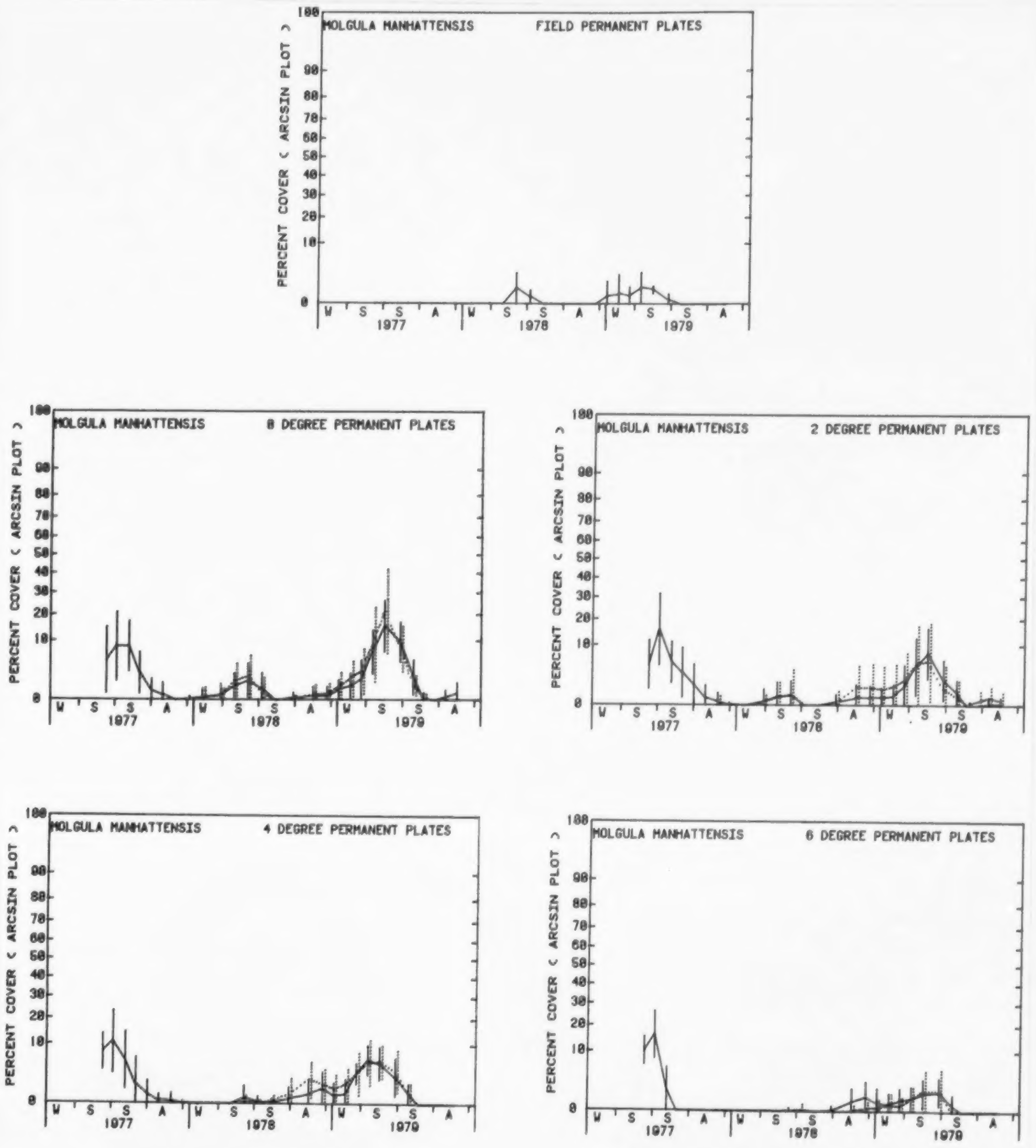

Figure 22. Mean (± SD) percent cover of the tunicate, Molgula manhattensis, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

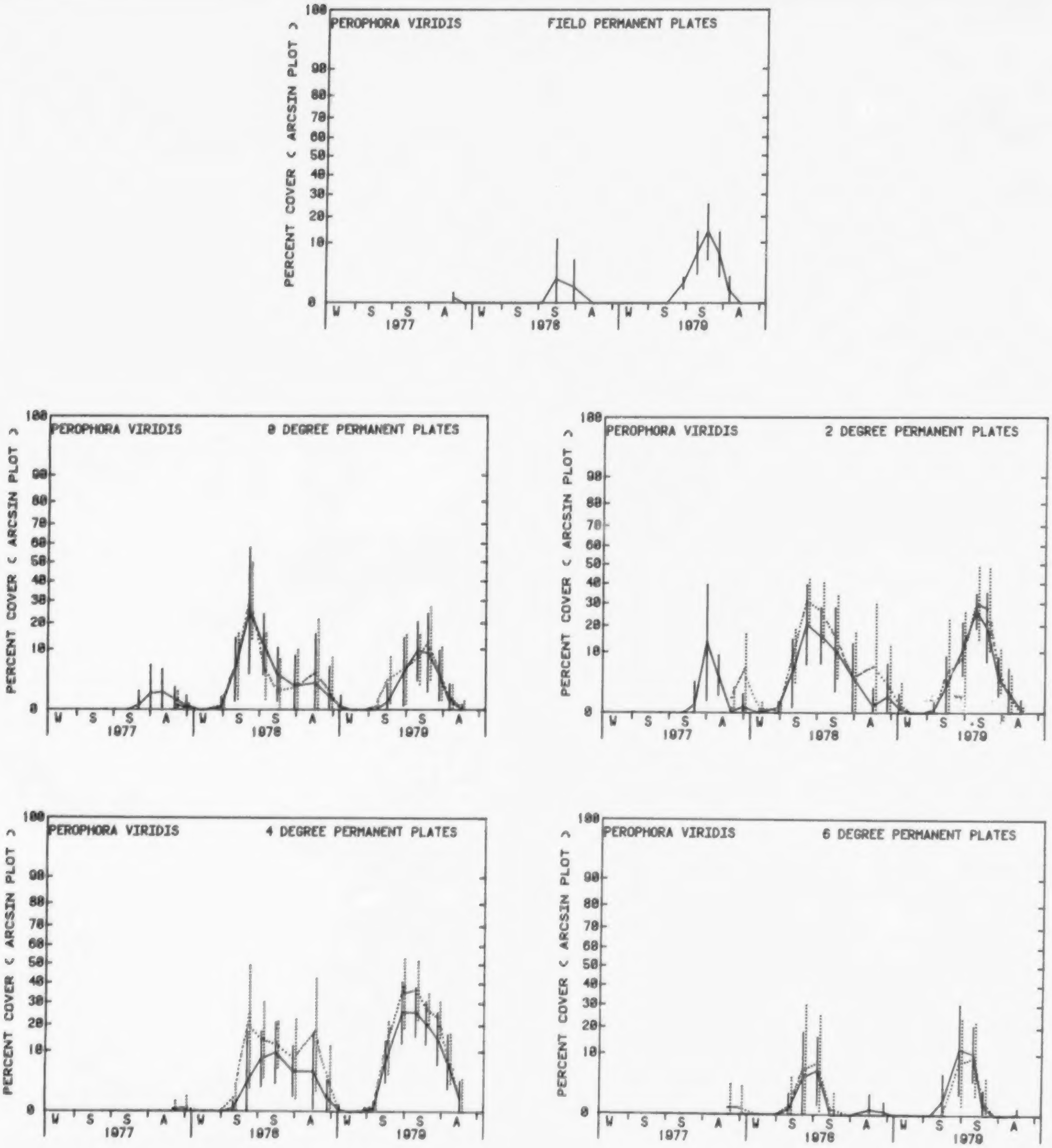

Figure 23. Mean (± SD) percent cover of the tunicate, Perophora viridis, on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

percent cover. In general, the 0°C, 2°C, and 4°C treatment plates had similar maximum mean percent cover, the greatest being 36.6 percent cover in July 1979 on 4°C Series "B" plates. Field plates had the same seasonal pattern of occurrence; the maximum mean abundance was 13.9 percent cover in August 1979. Percent cover on the 6°C plates was lower than in the other treatments.

Styela plicata, a large solitary tunicate, was the dominant species on field plates but occurred less frequently with very low abundance on laboratory plates (Table 26). On the field plates S. plicata had a seasonal pattern of abundance with maximum percent cover occurring in late spring to early summer and minimum in autumn. The maximum mean abundance was 74.6 percent cover in June 1978. In 1978 there was much greater variability in its occurrence than in 1979 since two of the three plates in the spring and summer of 1978 had high abundance with one plate having relatively low abundance; in 1979 all three plates had similar percent coverage.

UNOCCUPIED SPACE IN PERMANENT COMMUNITIES

In addition to percent coverage by species, a record was kept of percent unoccupied space on the plates in all treatments (Figure 24). In the field, the greatest unoccupied space on the plates occurred during the late summer and autumn with the least occurring in mid to late spring. There was slightly greater unoccupied space in autumn of 1979 than in 1978.

In all treatments within the laboratory system there was always greater unoccupied space on plates than there was on the field plates (Figure 24). In general, the 0°C, 2°C, and 4°C treatments were similar, showing progressively less seasonal variation in unoccupied space from 1977 to 1979. Throughout 1979 these three treatments had a fairly constant 10 - 20 percent unoccupied space. In the 6°C treatment unoccupied space varied greatly on a seasonal basis; highest values occurred in the late summer and early autumn (the warmest months), and lowest values occurred (except for 1977) in winter and spring. The 6°C unoccupied space curve is a mirror image of the percent cover curve for Crassostrea virginica (Figure 18) which suggests that changes in the abundance of oysters were the primary cause for changes in the percent of unoccupied space at 6°C. The Series "A" and "B" plates had very similar curves of unoccupied space in all four laboratory treatments.

ANALYSIS OF PERMANENT COMMUNITIES

Three methods were used to analyze the data for percent cover on permanent plates to describe changes in basic community structure on individual plates through the time course of the experiment: a comparison of numbers of species per plate, diversity on each plate, and a cluster analysis of the percent cover data for four of the time periods.

Figure 25 describes the pattern observed through time in the average number of species per plate on field and laboratory plates for both Series "A"

TABLE 26. STYELA PLICATA PERCENT COVER

Series A

Day	0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
470	9	.01	.09									
505	9	.04	.27									
575	9	.04	.27									
670	9	.06	.33									
705	9	.16	.70							9	.07	.28
735	9	.09	.37	9	.01	.09				9	.31	.62
765	9	.11	.42	9	.04	.25	9	.01	.07	9	.83	1.6
792	9	.06	.25	9	.06	.33	9	.13	.52	9	1.6	2.7
820	9	.14	.35	9	.06	.38	9	.26	.93	9	2.5	3.8
850	9	.27	.82	9	.06	.36	9	.31	1.1	9	2.0	3.4
890	9	.09	.31	9	.06	.34	9	.20	.60	9	1.0	2.0
925	9	.27	.83	9	.06	.38	9	.34	.89	9	.50	1.1
950	9	.34	1.1	9	.06	.33	9	.04	.15			
980	9	.18	.57	9	.08	.48						
1005	9	.21	.71	9	.08	.50						
1035	9	.15	.61	9	.08	.46						

(continued)

TABLE 26 (continued)

Series B

Day	Field			0 Degree			2 Degree			4 Degree			6 Degree		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
320	3	3.5	2.1												
348	3	7.9	8.7												
389	3	22.1	21.7												
436	3	19.4	15.3												
470	3	36.6	27.2												
505	3	53.1	32.6												
540	3	74.6	31.4												
575	3	69.8	41.6												
620	3	47.7	46.7												
670	3	14.9	13.2												
705	3	10.5	1.0												
735	3	34.5	3.7										9	.08	.23
765	3	39.0	3.0							9	.05	.28	9	.28	.85
792	3	38.3	6.6	9	.02	.15				9	.05	.23	9	.41	1.0
820	3	55.4	7.8	9	.03	.20				9	.16	.68	9	.43	1.3
850	3	68.3	12.8	9	.02	.10				9	.01	.09	8	.28	.93
890	3	70.2	7.8	9	.07	.29				9	.10	.44	8	.22	.75
925	3	36.5	6.5							9	.12	.50	8	.29	1.1
950	3	31.7	4.5				9	.01	.07	9	.09	.43	8	.04	.21
980	3	23.9	4.6				9	.02	.10	9	.03	.18			
1005	3	16.9	3.6				9	.02	.10						
1035	3	22.5	2.2	9	.02	.11	9	.01	.07						

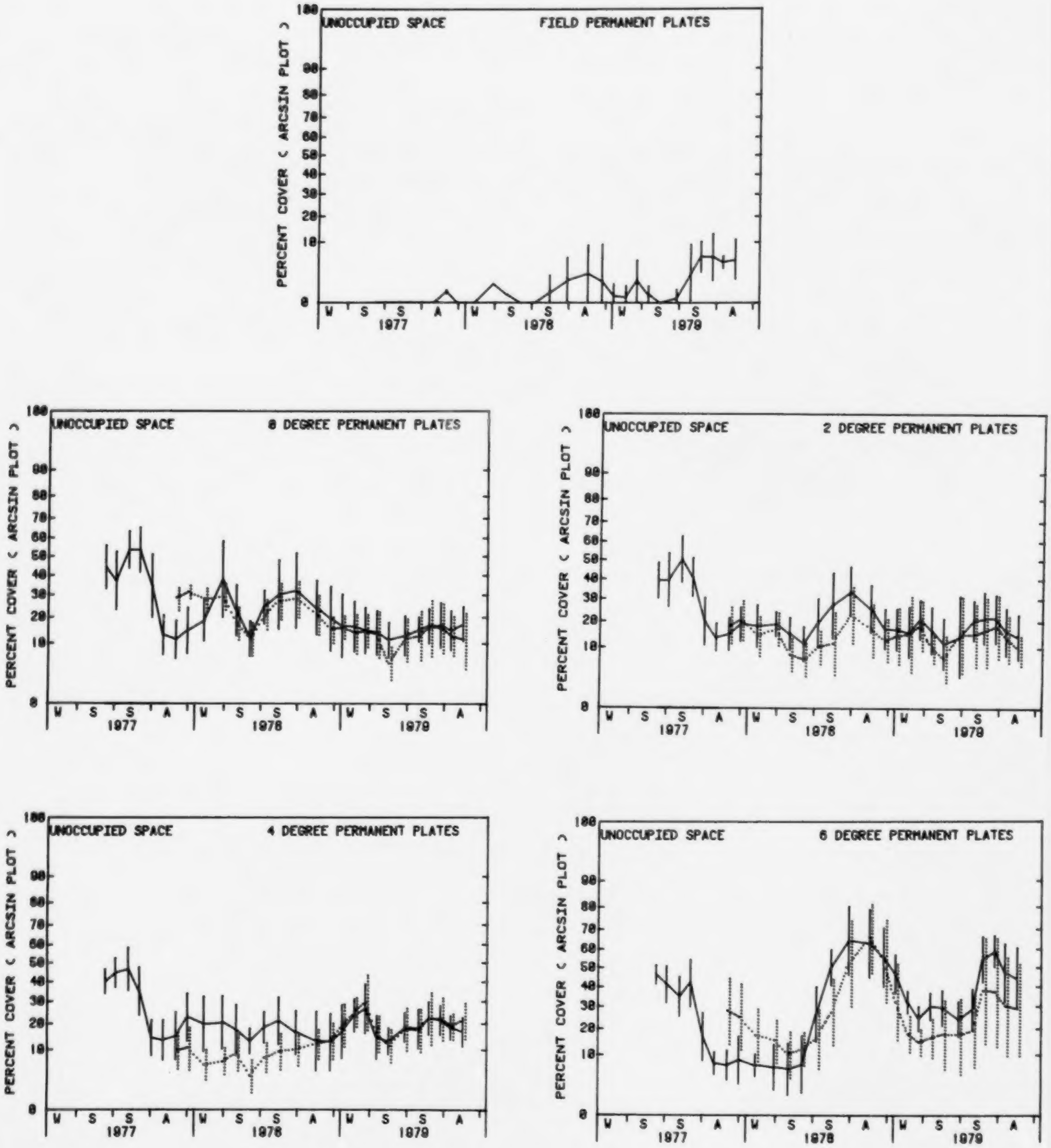

Figure 24. Mean (± SD) percent unoccupied space on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

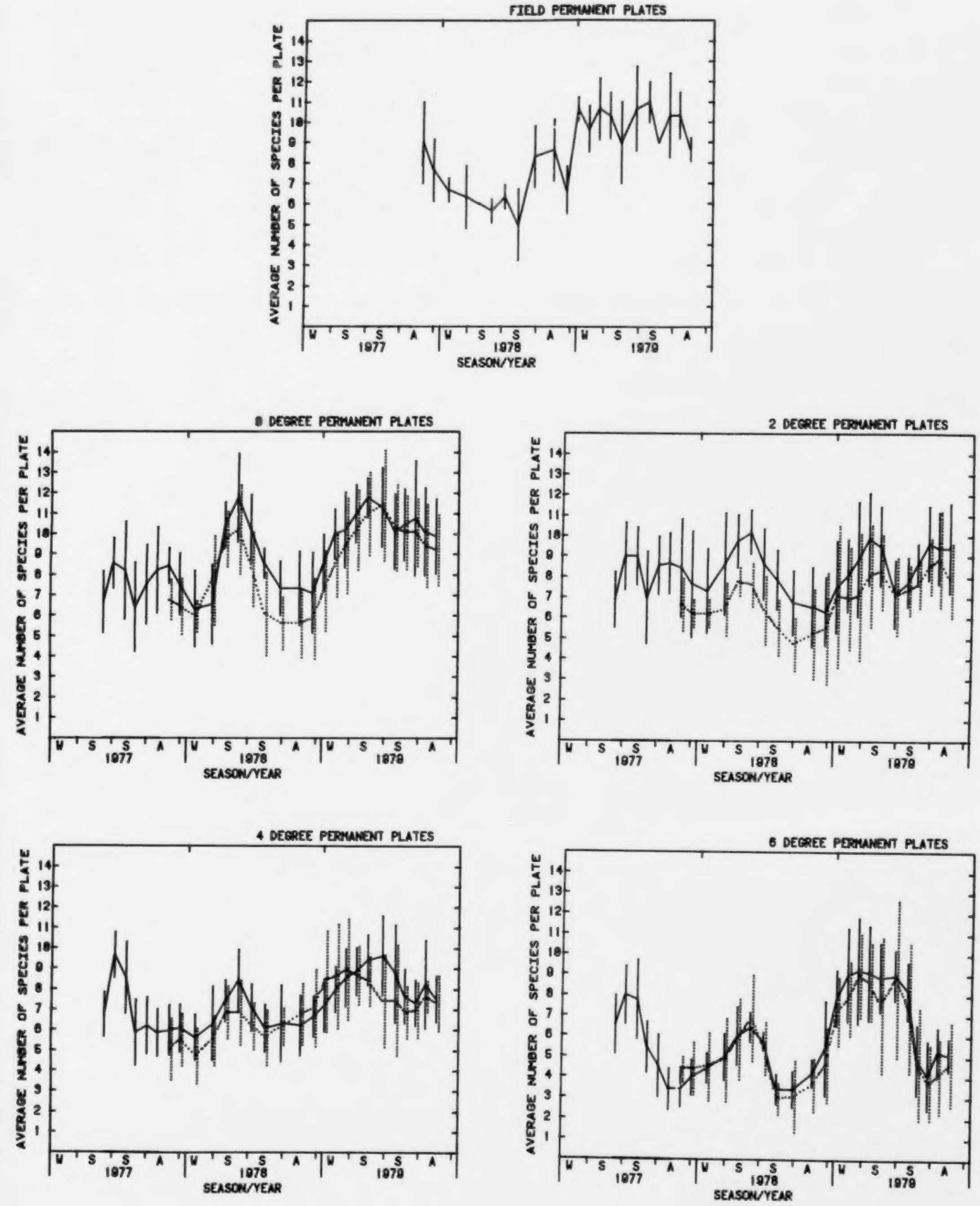

Figure 25. Mean (+ SD) number of species per plate on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

and Series "B." The standard deviations around the mean values are also plotted. Except for one time in the spring of 1978 there were no significant differences between the average number of species observed on field plates and that observed on laboratory plates at 0°C. In the field the number of species initially decreased from autumn of 1979 through summer of 1978 and then increased to a relatively constant maximum of 10 species per plate throughout 1979. In the laboratory system there was generally an annual pattern of maximum values in the late spring and minimum values in the late summer and autumn. As the temperature in the laboratory system increased the average number of species decreased. In the 2°C treatment, this was evident only in the spring; in the 4°C and 6°C treatments, this effect occurred during all seasons. Loss of species was greatest during late summer and autumn in the 6°C treatment.

Using percent cover data for importance values, the Shannon-Wiener diversity index was calculated for each plate for each time period and the results were plotted for each treament as a mean standard deviation for the plates in that treatment (Figure 26). The diversity values for field plates slowly increased (with oscillation) during the course of the experiment, reaching a maximum value of 2.7 in the summer of 1979. In the laboratory, 0°C plate diversity was relatively constant with an annual cycle such that the maximum value of 2.3 - 2.4 was reached in the spring of each year. Minimum values generally occurred in the winter. The pattern of diversity values at 2°C was almost identical to that observed at 0°C. At 4°C the diversity values were slightly lower than those at 0°C and 2°C with the exception of the initial values in Series "A" in the spring and summer of 1977. At 6°C diversity values were significantly lower than those at 0°C and 2°C (except for the initial Series "A" values of 1977). Maximum values of 1.7 - 1.8 occurred in the spring of 1978 and 1979, with minimum values of 0.5, 0.7, and 0.9 in the late summer and autumn of 1977, 1978, and 1979, respectively. These low diversity values which follow the warmest water temperatures were undoubtedly the result of differential heat death of many of the animals on 6°C plates.

Cluster analysis was done for four sampling periods (March and September, 1978 and 1979) using two sets of percent cover data: (1) all Series "A" laboratory plates and field plates, and (2) all Series "B" laboratory plates and field plates. The choice of spring and fall sampling dates for the analysis of all Series "A", Series "B", and field plates was based on the times of maximum and minimum diversity and number of species, which followed by one month the periods of maximum and minimum ambient water temperatures. Each of the two analyses used data from 39 separate plates (three field, and nine each from the laboratory treatments), except September 1979 of Series "B" where one 6°C plate was missing. Table 27 gives the results of this cluster analysis. A similarity level of 0.67 was chosen for identifying cluster groups to facilitate discussion of the results. Choosing a higher level would have resulted in more groups but would not have changed the basic interpretation of these data. The choice of a lower similarity level would have resulted in fewer groups; however, it also would have provided less information for discussion.

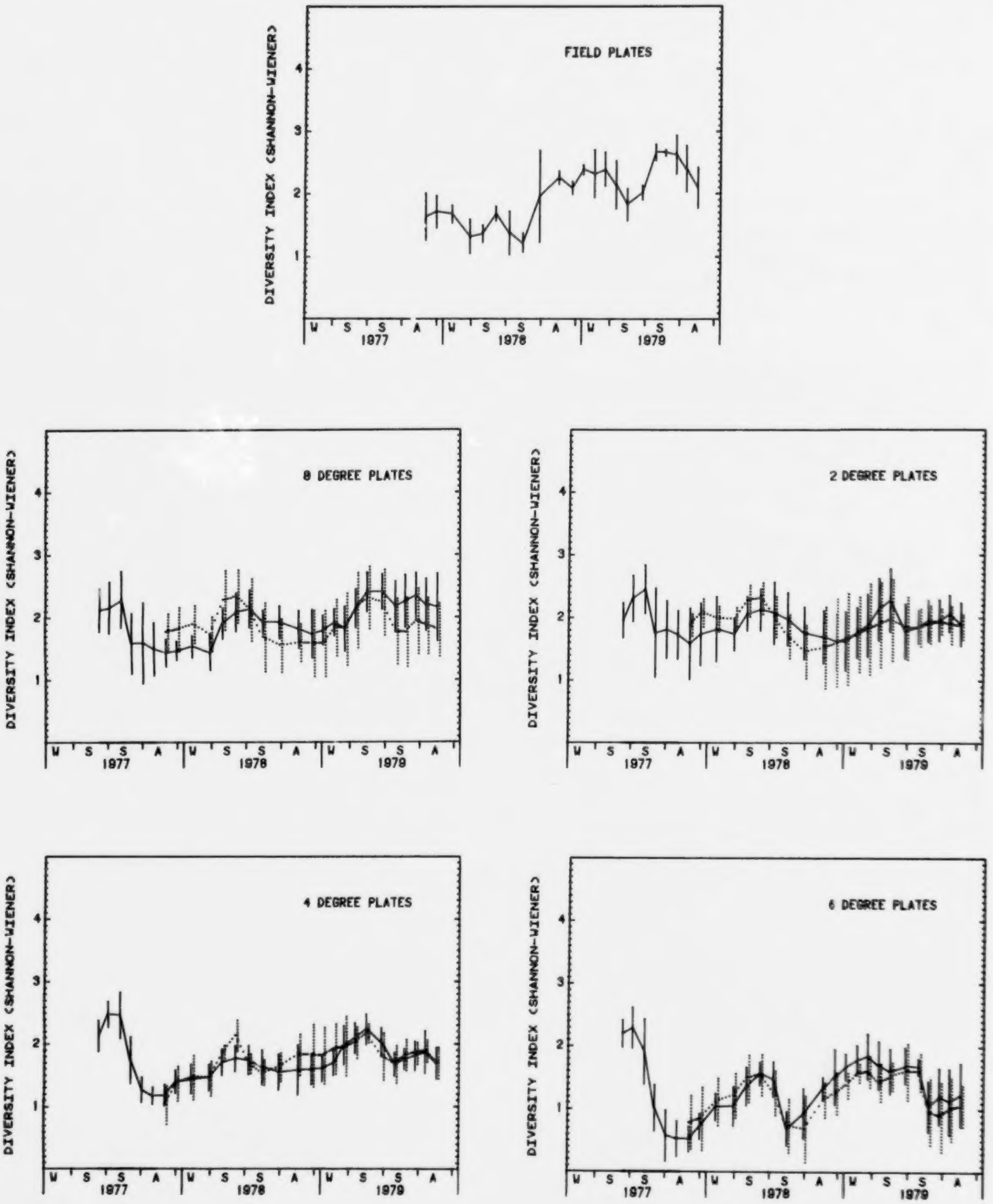

Figure 26. Mean (± SD) diversity calculated using percent cover data on permanent plates through time for five treatments (solid line - "A" series; dotted line - "B" series).

TABLE 27. RESULTS OF CLUSTER ANALYSES BASED ON PERCENT COVER BY SPECIES IN PERMANENT COMMUNITIES ON (1) SERIES A AND FIELD PLATES, AND (2) SERIES B AND FIELD PLATES. ALTHOUGH THE ANALYSES INCLUDED ALL SPECIES PRESENT ON THE PLATES, ONLY THOSE SPECIES HAVING AN AVERAGE OF AT LEAST 10 PERCENT ARE GIVEN.

Date	Cluster Group	Species	Average Cover (%)	Comments
Series A and Field Plates:				
March 1978	1	*Crassostrea virginica*	68	All 36 laboratory plates clustered at 0.82.
		Spirorbis borealis	17	
		Corophium acherusicum	17	
	2	*Schizoporella errata*	69	All 3 field plates clustered at 0.91. Groups 1 and 2 clustered at 0.01.
		Styela plicata	21	
September 1978	1	*Crassostrea virginica*	45	All lab plates except 1-0°C and 1-6°C clustered at 0.75.
		Spirorbis borealis	28	
	2	*Styela plicata*	69	2 field plates clustered at 0.69.
		Schizoporella errata	13	
	3	*Bugula avicularia*	11	1-6°C plate clustered with Group 1 at 0.57.
		Crassostrea virginica	10	
	4	*Halichondria bowerbanki*	38	1-0°C plate clustered with Groups 1 and 3 at 0.53.
		Crassostrea virginica	20	
		Geukensia demissa	14	
		Spirorbis borealis	11	
	5	*Schizoporella errata*	62	1 field plate clustered with Group 2 (other field plates) at 0.26. All groups clustered at 0.11.
		Diadumene leucolena	23	
		Hydroides dianthus	11	
March 1979	1	*Crassostrea virginica*	52	All laboratory plates except 2-0°C, 2-2°C, and 1-4°C clustered at 0.83.
		Spirorbis borealis	15	
	2	*Spirorbis borealis*	55	2-2°C and 1-4°C plates clustered at 0.98 and with Group 1 at 0.66.
		Crassostrea virginica	27	

(continued)

TABLE 27. (continued)

Date	Cluster Group	Species	Average Cover (%)	Comments
March 1979 (cont)	3	*Styela plicata*	28	All 3 field plates clustered at 0.85. Clustered with all other groups at 0.09.
		Schizoporella errata	30	
		Balanus spp.	13	
		Aiptasia pallida	12	
	4	*Halichondria bowerbanki*	66	1-0°C plate clustered with Groups 1 and 2 at 0.27.
		Crassostrea virginica	18	
	5	*Bugula avicularia*	67	1-0°C plate clustered with Groups 1, 2, and 4 at 0.25.
		Halichondria bowerbanki	15	
September 1979	1	*Crassostrea virginica*	48	All laboratory plates except 2-0°C and 2-2°C clustered at 0.80.
		Spirorbis borealis	15	
	2	*Corophium acherusicum*	28	1-0°C plate clustered with Group 1 at 0.55
		Halichondria bowerbanki	19	
		Crassostrea virginica	17	
	3	*Haliclona loosanoffi*	45	1-0°C and 1-2°C plate clustered at 0.87. Clustered with Groups 1 and 2 at 0.50.
		Crassostrea virginica	23	
		Halichondria bowerbanki	11	
	4	*Aiptasia pallida*	27	All 3 field plates clustered at 0.74. Clustered with Groups 1, 2, and 3 at 0.37.
		Styela plicata	24	
		Crassostrea virginica	15	
		Haliclona loosanoffi	12	
		Pennaria tiarella	12	
	5	*Halichondria bowerbanki*	77	1-2°C plate clustered with all other groups at 0.13.
		Corophium acherusicum	11	
Series B and Field Plates:				
March 1978	1	*Schizoporella errata*	69	All 3 field plates clustered at 0.91. Clustered with Groups 2 and 3 at 0.01.
		Styela plicata	21	
	2	*Crassostrea virginica*	63	6-0°C and all 9-6°C plates clustered at 0.84.
		Corophium acherusicum	24	

(continued)

TABLE 27. (continued)

Date	Cluster Group	Species	Average Cover (%)	Comments
March 1978 (cont)	3	*Spirorbis borealis*	43	3-0°C, all 9-2°C, and all 9-4°C plates clustered at 0.82. Clustered with Group 2 at 0.60.
		Corophium acherusicum	28	
		Crassostrea virginica	19	
		Hydroides dianthus	12	
September 1978	1	*Crassostrea virginica*	39	All laboratory plates clustered at 0.67.
		Spirorbis borealis	32	
	2	*Styela plicata*	69	2 field plates clustered at 0.69.
		Schizoporella errata	12	
	3	*Schizoporella errata*	62	1 field plate clustered with Group 2 at 0.27. All groups clustered at 0.11.
		Diadumene leucolena	23	
		Hydroides dianthus	11	
March 1979	1	*Crassostrea virginica*	59	6-0°C, 8-2°C, all 9-4°C, and all 9-6°C plates clustered at 0.85.
		Spirorbis borealis	17	
	2	*Bugula avicularia*	51	2-0°C plates clustered at 0.92.
		Crassostrea virginica	14	
		Schizoporella errata	11	
	3	*Styela plicata*	38	All 3 field plates clustered at 0.85. Clustered with all other groups at 0.10.
		Schizoporella errata	30	
		Balanus spp.	13	
		Aiptasia pallida	12	
	4	*Anguinella palmata*	23	1-2°C plate clustered with Group 1 at 0.62.
		Crassostrea virginica	19	
		Bugula avicularia	10	
	5	*Halichondria bowerbanki*	28	1-0°C plate clustered with Group 1 at 0.58. Groups 1, 2, 4, and 5 clustered at 0.41.
		Bugula avicularia	16	
		Crassostrea virginica	12	
		Schizoporella errata	10	
September 1979	1	*Crassostrea virginica*	56	7-0°C, 8-2°C, all 9-4° and all 9-6°C plates clustered at 0.81.
		Spirorbis borealis	14	
	2	*Haliclona loosanoffi*	35	1-2°C plate clustered with Group 1 at 0.66.
		Crassostrea virginica	28	
		Perophora viridis	10	

(continued)

TABLE 27. (continued)

Date	Cluster Group	Species	Average Cover (%)	Comments
September 1979 (cont)	3	*Hydroides dianthus*	22	1-0°C plate clustered with Groups 1 and 2 at 0.56.
		Perophora viridis	20	
		Crassostrea virginica	17	
		Ascidia interrupta	15	
	4	*Aiptasia pallida*	27	All 3 field plates clustered at 0.74. Clustered with Groups 1, 2, and 3 at 0.36.
		Styela plicata	24	
		Crassostrea virginica	15	
		Haliclona loosanoffi	12	
		Pennaria tiarella	12	
	5	*Halichondria bowerbanki*	53	1-0°C plate clustered with all other groups at 0.25.
		Corophium acherusicum	30	

The results (Table 27) indicate the persistent difference between field and laboratory communities throughout the experiment. Field plates always clustered together as a group above the 0.67 similarity level and usually clustered with all the laboratory plates at approximately 0.1. It can be concluded from these anlayses that field communities were significantly different from laboratory communities.

Field plates in March 1978 were dominated by an encrusting bryozoan, *Schizoporella errata*. In September 1978, a tunicate, *Styela plicata*, had become dominant on two of the three plates, with *Schizoporella errata* still dominant on one plate (the one time when the three field plates did not cluster together above 0.67). In March 1979 *Styela plicata* and *Schizoporella errata* were co-dominant, and in September 1979 an anemone, *Aiptasia pallida*, was co-dominant with *Styela plicata* while *Schizoporella errata* had almost disappeared from the plates. These results were identical, both in sequence and timing of changes in *Schizoporella*, to results reported by Sutherland (1978) in a paper entitled, "Functional roles of *Schizoporella* and *Styela* in the fouling community at Beaufort, North Carolina."

In a comparison of plates in the laboratory among the different treatments (Table 27) it is apparent that there was no influence of elevated temperatures on basic community structure. The only exception was the March 1978 Series "B" plates on which two distinct communities (each with an equal number of plates) could be recognized. The first was a community dominated by the oyster *Crassostrea virginica*; this community occurred on six plates in the 0°C treatment and all nine plates in the 6°C treatment. The second community was dominated by the serpulid *Spirorbis borealis* and occurred on three plates from 0°C, all nine plates from 2°C, and all nine plates from 4°C treatments. At other times most laboratory plates clustered together into one group with a few individual plates from various treatments having distinct communities. One characteristic of these individual plates appeared to be the increasing importance (through time) of the sponges *Halichondria bowerbanki* and *Haliclona loosanoffi*, which suggests that even though sponges recruited slowly and on few plates, once established, they outcompeted oysters for space and formed a distinctly different community. The species which dominated most Series "A" and "B" plates in all laboratory treatments were *Crassostrea virginica* and *Spirorbis borealis*. Even though many other species were influenced by temperature treatments in time of appearance and abundance, these two major species were always present in all treatments in percent cover great enough to ensure their dominance in the community. Two of these cluster analyses (September 1979, Series "A" and "B") are presented in Figures 27 and 28 as examples of the results obtained. For both series it can be seen that the different community groups, as indicated by the cluster analysis, are not related to temperature treatment within the laboratory. The field plates form a distinct assemblage (Group 4) which is different from that on laboratory plates. This group was dominated by five species which included a sea anemone, a tunicate, oysters, a sponge, and a hydroid. Within the laboratory the largest group in both Series "A" and Series "B" was Group 1 which was the oyster/polychaete community present on a mixture of plates from all temperature treatments. Groups 2, 3, and 5 in Series "A" and "B" were composed of only one or two plates each in the 0°C and 2°C treatments. In

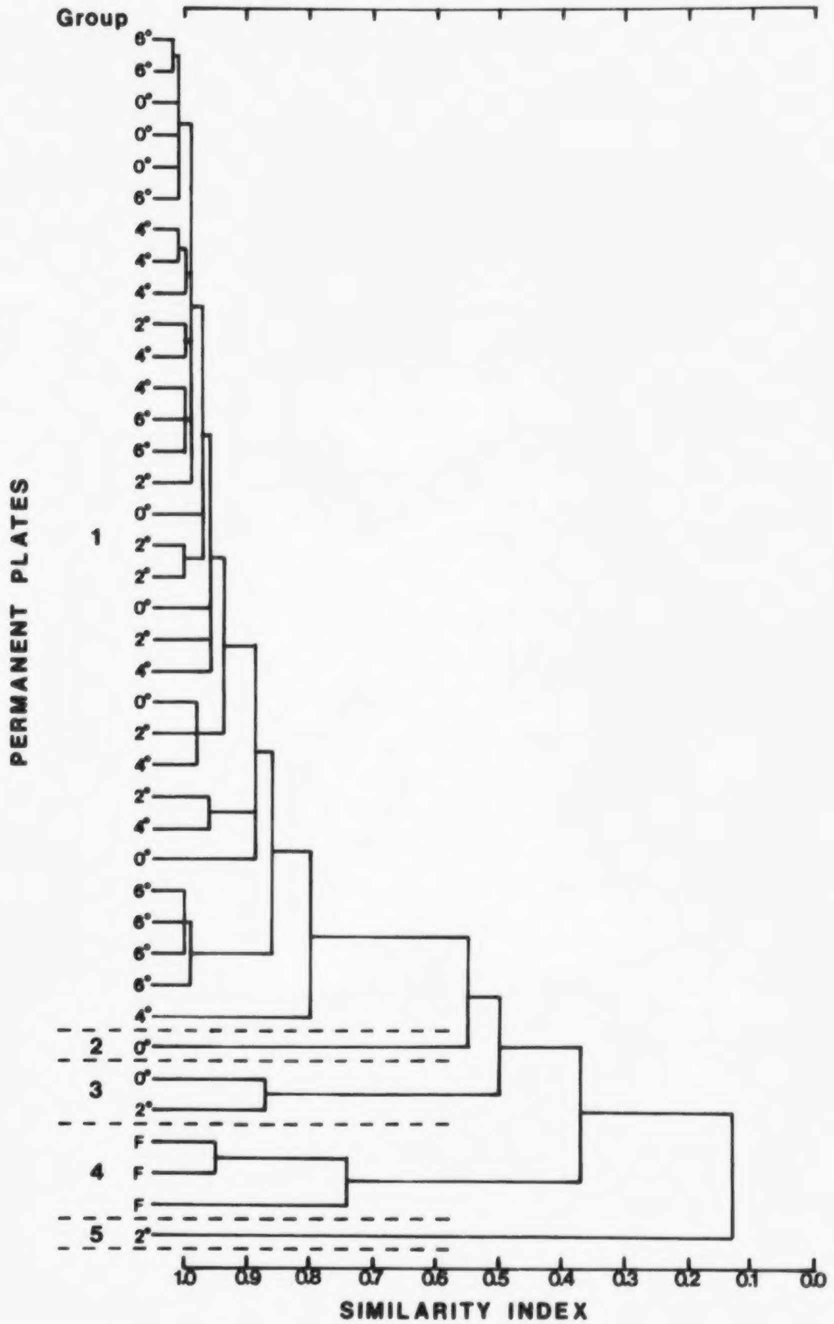

Figure 27. Results of cluster analysis of percent cover data for "A" series permanent plates on September 7, 1979. Species groups are the same as those in Table 27, "A" series, September, 1979.

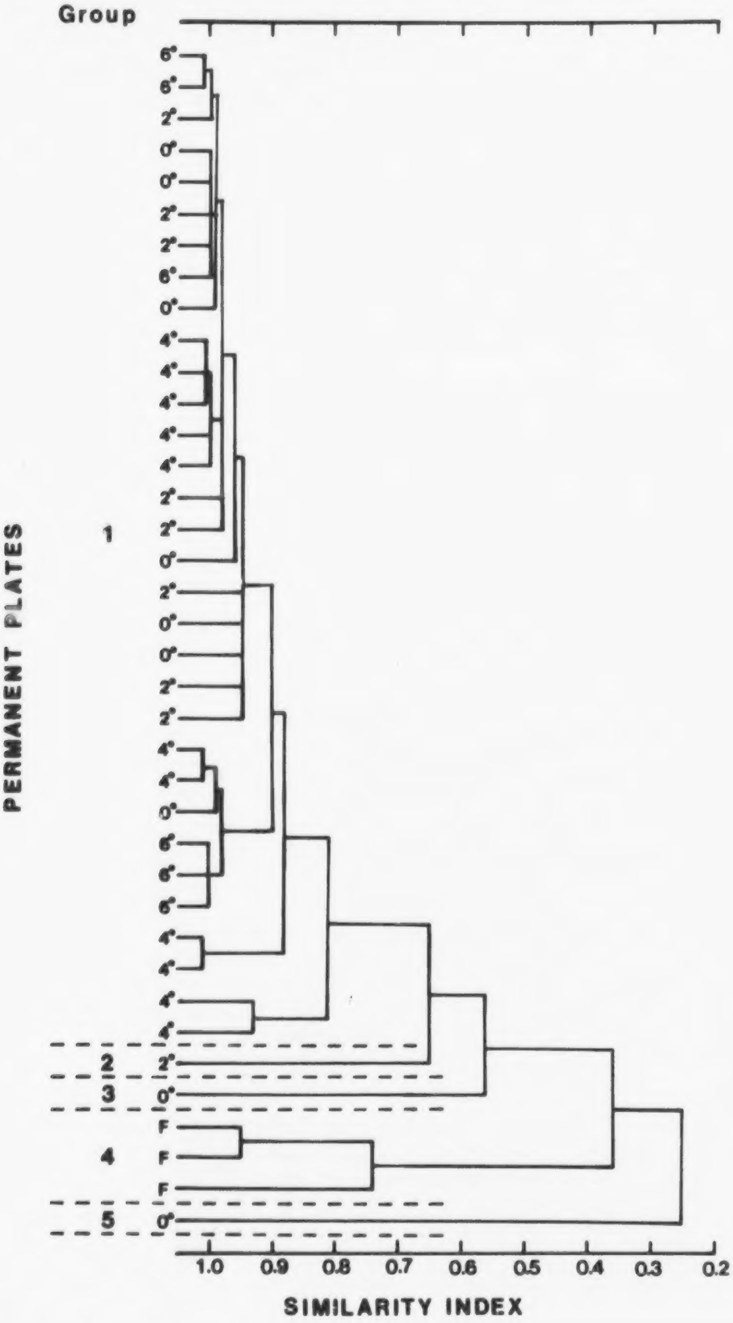

Figure 28. Results of cluster analysis of percent cover data for "B" series permanent plates on September 7, 1979. Species groups are the same as those in Table 27, "B" series, September, 1979.

four of the six groups the dominant organism was a sponge. As previously discussed it was apparent that sponges, particularly Haliclona loosanoffi and Halichondria bowerbanki, were becoming increasingly important on a few laboratory plates.

From the results of cluster analysis it is concluded that community structure in the laboratory was significantly different from community structure on field plates, a conclusion which also could be reached based upon information presented in preceding sections on percent cover by individual species. Within the laboratory system, communities from any one treatment in series never clustered together without the inclusion of several communities from other treatments. Furthermore there was never any obvious hierarchy of clustering which could be associated with increasing temperatures in the various treatments. In conclusion, no distinct groupings of community type could be related to temperature treatment.

In addition to the cluster analysis described above, a second cluster analysis was performed in which the mean percent cover for plates in a specific treatment (three plates in the field and nine in each of the laboratory treatments) was calculated for 22 dates beginning November 1977 when Series "B" was first sampled. Table 28 presents the similarity values at which all laboratory treatments clustered together ("All") and similarity values at which all "A" and "B" series plates clustered together for each of the four temperature treatments. In the first time period clustered (November 1977), there were no patterns observed except that the 6°C Series "A" and "B" plates clustered together at a similarity level of 1.00. All groups clustered together at a relatively low similarity of 0.38. As time passed, successive clustering values for all plates together became progressively greater which indicated an increasing similarity of mean percent composition of all communities on laboratory plates. For all of the 22 time periods the 6°C Series "A" and "B" plates always clustered together with a similarity value of 1.00. By the end of the experiment "A" and "B" plates from each treatment were clustering together (1.00 similarity) before clustering with each other at similarities greater than 0.90. Because of the high similarity levels among these treatments it can be concluded that mean community structures, by the end of the experiment, were almost identical and that increasing temperatures did not result in the appearance of different communities.

ANCILLARY STUDIES

Summary

Most of the members of the fouling community depend on suspended material for food and on suspended larvae for recruitment. Therefore, ancillary studies of flow rates, chlorophyll a values, and clearance rates were designed to investigate the influence of plate communities on the concentration of phytoplankton suspended in the seawater as it flowed through the experimental system in the laboratory. Results of these studies suggested that the system was probably food stressed during the warmer months of the year in all temperature treatments, and throughout the year at the 6°C differential.

TABLE 28. SIMILARITY VALUES (0.0 - 1.00) FROM CLUSTER ANALYSIS OF MEAN PERCENT COVER DATA FROM THE LABORATORY TREATMENTS. VALUES ARE GIVEN FOR SIMILARITY OF ALL EIGHT TREATMENTS TOGETHER ("ALL"). FOR INDIVIDUAL TREATMENTS THE VALUES ARE THE SIMILARITIES AT WHICH THE "A" AND "B" SERIES CLUSTERED TOGETHER IN EACH TREATMENT.

Date	ALL	0° A,B	2° A,B	4° A,B	6°C A,B
11/77	0.38	0.75	0.38	0.38	1.00
12/77	0.39	0.68	0.68	0.39	1.00
1/78	0.54	0.82	0.54	0.54	1.00
3/78	0.47	0.72	0.72	0.47	1.00
4/78	0.66	0.95	0.66	0.66	1.00
5/78	0.74	0.87	0.74	0.74	1.00
6/78	0.68	0.92	0.68	0.68	1.00
7/78	0.68	0.93	0.91	0.91	1.00
9/78	0.78	0.97	0.98	1.00	1.00
10/78	0.83	1.00	0.98	0.98	1.00
12/78	0.85	1.00	1.00	1.00	1.00
1/79	0.84	1.00	1.00	0.99	1.00
2/79	0.86	1.00	1.00	0.97	1.00
3/79	0.89	1.00	1.00	0.95	1.00
4/79	0.90	1.00	1.00	0.95	1.00
5/79	0.83	1.00	1.00	0.96	1.00
6/79	0.93	1.00	1.00	1.00	1.00
7/79	0.95	0.97	1.00	0.99	1.00
8/79	0.89	0.99	1.00	1.00	1.00
9/79	0.92	1.00	1.00	1.00	1.00
10/79	0.93	1.00	1.00	1.00	1.00
11/79	0.95	1.00	1.00	1.00	1.00

Flow Rates

An open, flowing seawater system more closely simulates natural conditions than a closed system while still allowing some manipulation of the physical environment. The rate of flow selected for such systems is always a compromise between the negative influences of relatively slow flows and the impossibility of duplicating "natural" flows found in the field. The flow rate through the tanks for this study was selected to provide a moderate current and a turnover time of 45 - 60 min. Flow rates were measured through individual tanks as part of the monitoring of conditions in the experimental tanks.

Flow rates were measured for two extended periods between 1976 and 1979 (Table 29). Between 8 November 1976 and 20 April 1977, flow volumes were measured on 36 occasions for all experimental tanks. Measurements were made during the day after any slow flows from the previous night had been corrected. Thus, flows measured represent the maximum for each tank at this time. There was little difference in flow rates among tanks; the minimum rate was recorded for Tank 8 (10.9 l/min) which is 87 percent of the maximum observed (12.6 l/min for Tank 11). Between 2 January 1979 and 13 November 1979 flow volumes were measured before cleaning each tank and again one to five days after cleaning. The tanks were normally cleaned every three to four weeks. The data for the flow rate (for each tank) after cleaning were compared (for each tank) with those data collected before cleaning. Although in 11 of the 12 tanks mean flow volumes were slightly greater after cleaning compared to before cleaning, none of the differences were significant. Hence all of these data were pooled and used in compiling Table 29. Flow rates during the second period ranged from a maximum of 11.9 l/min (Tank 12) to a minimum of 9.2 l/min (Tank 6), which is 77 percent of the maximum.

Chlorophyll a

Measurement of the concentration of chlorophyll a in marine waters provides an estimate of the standing crop or biomass of phytoplankton. Since the dominant species in the fouling communities are suspension feeders, measurements of chlorophyll a at various points in the experimental system can provide insight into the relative availability of food for the communities in the different treatments at different seasons of the year.

Figures 29 - 31 present the data collected in a series of 12-hour monitoring experiments in 1978 and 1979 for one set of tanks (ambient, 2°C, 4°C, and 6°C). On each figure the concentration of chlorophyll a is plotted at the pump intake (DOCK), the heater tank (H), and the experimental tank (E). On 1 February 1978 (Figure 29) the average concentration of chlorophyll a at the pump intake for the 12-hour period was 5.16 micrograms per liter. In the heater tanks which fed the four experimental tanks, the average concentration was 88 - 94 percent of that at the dock, which suggests the system removed approximately 10 percent of the phytoplankton before reaching the experimental tanks. The experimental tanks had the following average concentrations of chlorophyll a as compared to the heater tanks: ambient, 90 percent; 2°C,

TABLE 29. SUMMARY OF FLOW RATE MEASUREMENTS FOR THE EXPERIMENTAL TANKS FOR TWO PERIODS. Δ T = TEMPERATURE TREATMENT, N = NUMBER, F.R. = MEAN FLOW RATE (LITERS/MINUTE), S.D. = STANDARD DEVIATION, AND C.V. = COEFFICIENT OF VARIATION.

		8 November 1976 - 20 April 1977				2 January - 13 November 1979			
Tank	Δ T	N	F.R. (l/min)	S.D. (±)	C.V. (%)	N	F.R. (l/min)	S.D. (±)	C.V. (%)
1	2	36	12.2	0.8	6.5	26	10.8	2.3	21
2	4	36	12.0	1.1	9.2	22	11.5	2.7	33
3	6	36	12.2	0.8	6.6	24	11.1	2.3	21
4	A	36	12.0	1.2	10.0	24	10.9	1.4	13
5	4	36	11.5	0.8	7.0	24	10.3	2.9	28
6	2	36	12.0	1.1	9.2	24	9.2	3.1	34
7	A	36	12.4	1.1	9.8	26	11.3	3.2	28
8	6	35	10.9	1.4	13.0	28	10.8	2.5	23
9	6	36	11.4	1.4	12.0	28	11.0	2.6	24
10	A	35	11.2	1.0	8.9	30	11.0	2.3	21
11	4	36	12.6	0.8	6.3	28	11.6	2.5	22
12	2	36	12.2	1.6	13.0	28	11.9	2.1	18

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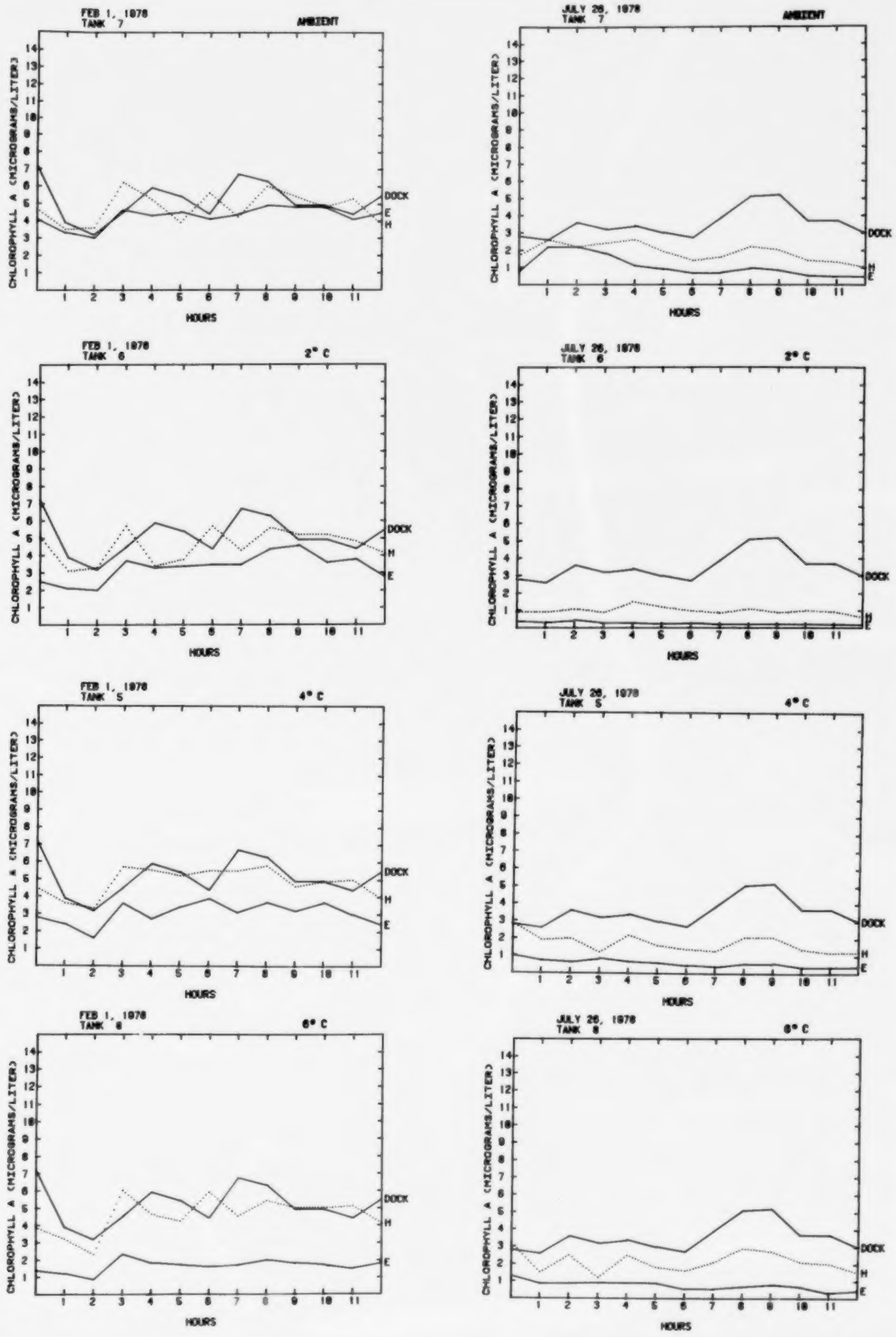

Figure 29. Chlorophyll a concentrations over a twelve-hour period at three locations (Dock = pump intake, H = heater tank, E = experimental tank). Data are presented for four treatments (Ambient, 2°C, 4°C, and 6°C) on two dates (1 February 1978; 26 July 1978).

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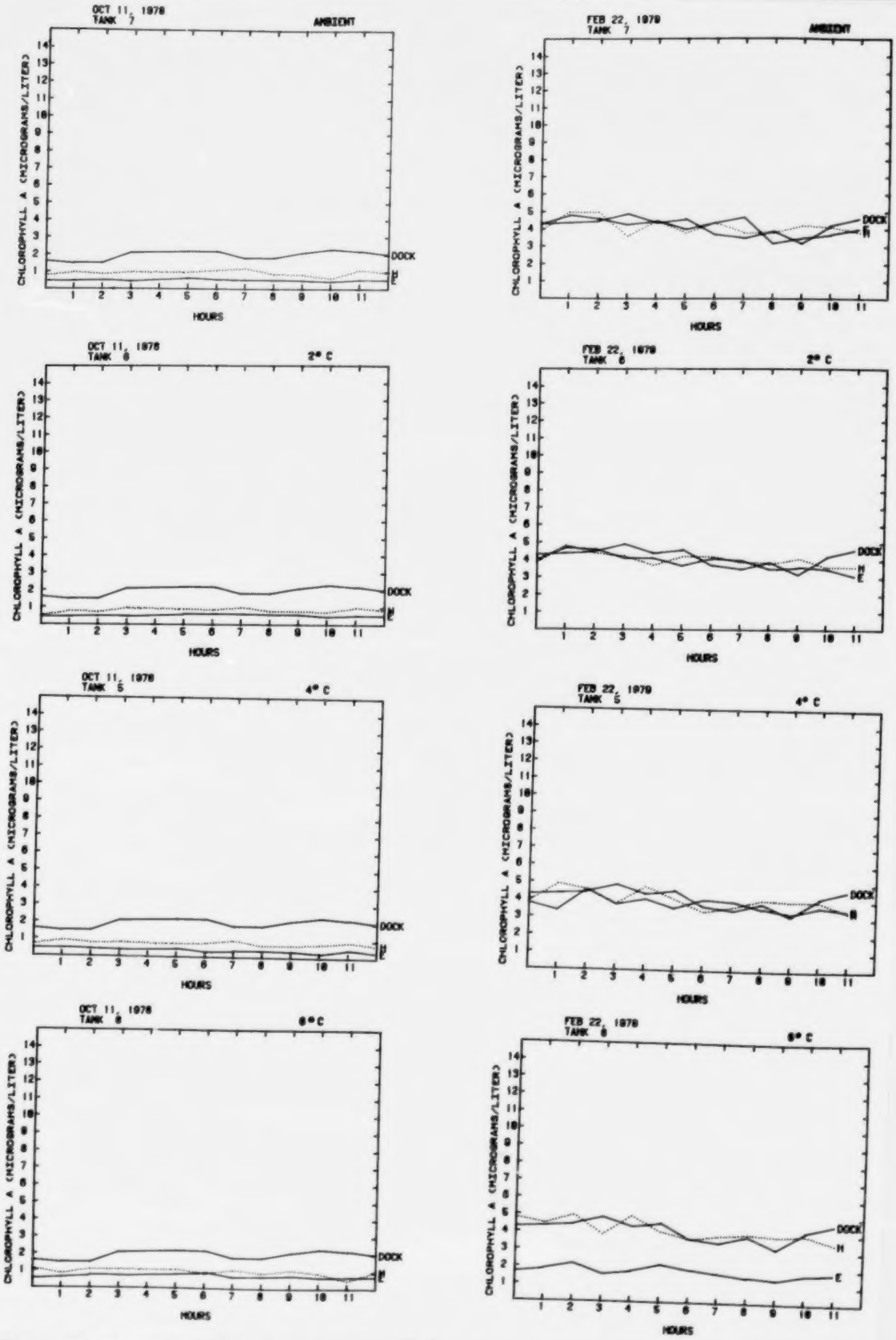

Figure 30. Chlorophyll a concentrations over a twelve-hour period at three locations (Dock = pump intake, H = heater tank, E = experimental tank). Data are presented for four treatments (Ambient, 2°C, 4°C, and 6°C) on two dates (11 October 1978; 22 February 1979).

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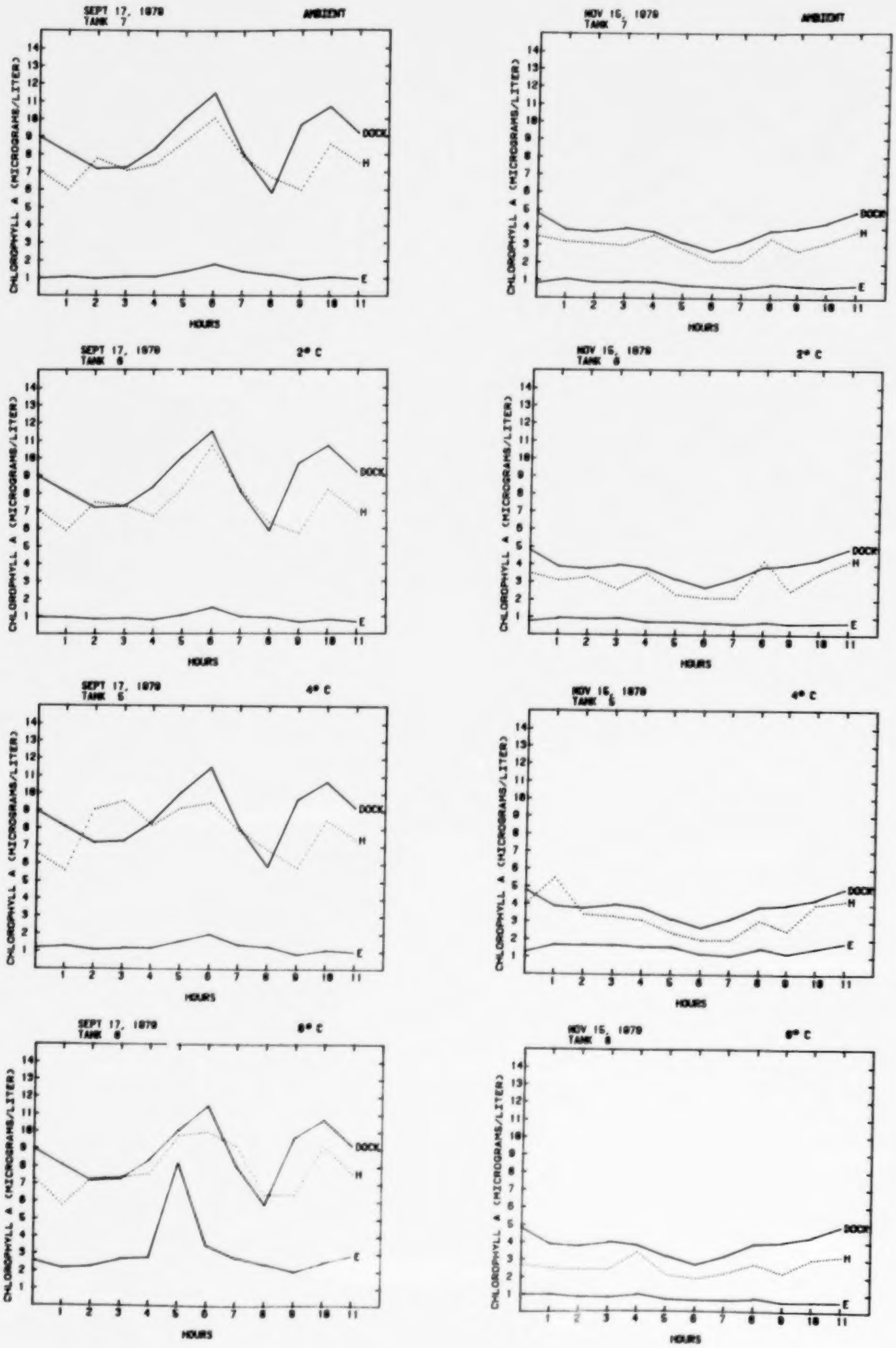

Figure 31. Chlorophyll a concentrations over a twelve-hour period at three locations (Dock = pump intake, H = heater tank, E = experimental tank). Data are presented for four treatments (Ambient, 2°C, 4°C, and 6°C) on two dates (17 September 1979; 15 November 1979).

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73 percent; 4°C, 63 percent; and 6°C, 36 percent. In February 1979 (Figure 30) a significant reduction in chlorophyll a occurred only in the 6°C tank. On 26 July 1978 (Figure 29) the heater tanks had the following chlorophyll a concentrations compared to the intake (dock) which averaged 3.53 micrograms per liter: ambient, 53 percent; 2°C, 28 percent; 4°C, 51 percent; and 6°C, 61 percent. The experimental tanks had the following concentrations relative to the heater tanks feeding them: ambient, 56 percent; 2°C, 27 percent; 4°C, 33 percent; and 6°C, 35 percent. Combining the reduction in phytoplankton in the system up to the heater tanks with that in the experimental tanks (tank concentration ÷ intake (dock) concentration x 100) the following was observed: ambient, 30 percent; 2°C, 9 percent; 4°C, 17 percent; and 6°C, 21 percent. In October 1978 (Figure 30) the pattern of reduction in chlorophyll a was similar to that observed in July 1978. Thus in the summer when water temperatures were highest and the energetic needs of the communities the greatest, the food availability (at least for phytoplankton suspension feeders in the fouling communities) was reduced to less than one-third and in one case to less than one-tenth that available to the communities suspended under the dock in the field. In 1979 an accelerated cleaning schedule (once every three weeks) resulted in a significant increase during the summer (September 1978, Figure 31) in the percent phytoplankton in the heater tanks feeding the experimental tanks: ambient, 87 percent; 2°C, 84 percent; 4°C, 89 percent; and 6°C, 89 percent. However, because of the effects of the communities themselves, the concentration of phytoplankton available to the organisms in the laboratory tanks was still only one-tenth to one-third that available to communities in the field: ambient, 14 percent; 2°C, 10 percent; 4°C, 14 percent; and 6°C, 30 percent. These large reductions were also noted in the late fall (Figure 31).

The conclusion that there was a food stress for suspension feeders in the communities in the experimental tanks is further substantiated by the chlorophyll a synoptic monitoring experiments in which all experimental tanks were sampled weekly during 1979. These experiments (Figures 32 - 34) show that during the warmer months of the year, communities in all tanks were exposed to low phytoplankton concentrations compared to field conditions and, in the 6°C above ambient treatment, the phytoplankton concentrations were low during the entire year.

Clearance Rates

During 1979 experiments were performed to determine the clearance rates of the assemblages of organisms on permanent plates held in the experimental system. The object was to estimate the rate of removal of suspended material by the communities to document the influence the communities had on the available suspended food material in these tanks.

During the summer (May - August) of 1979 a series of clearance rate experiments were performed to investigate the influence of time of day and phytoplankton concentration on the clearance rate of communities. These initial experiments were followed in August by experiments to determine the clearance rate of each individual permanent plate assemblage. Clearance rate of each assemblage was again measured in December just prior to shutting down

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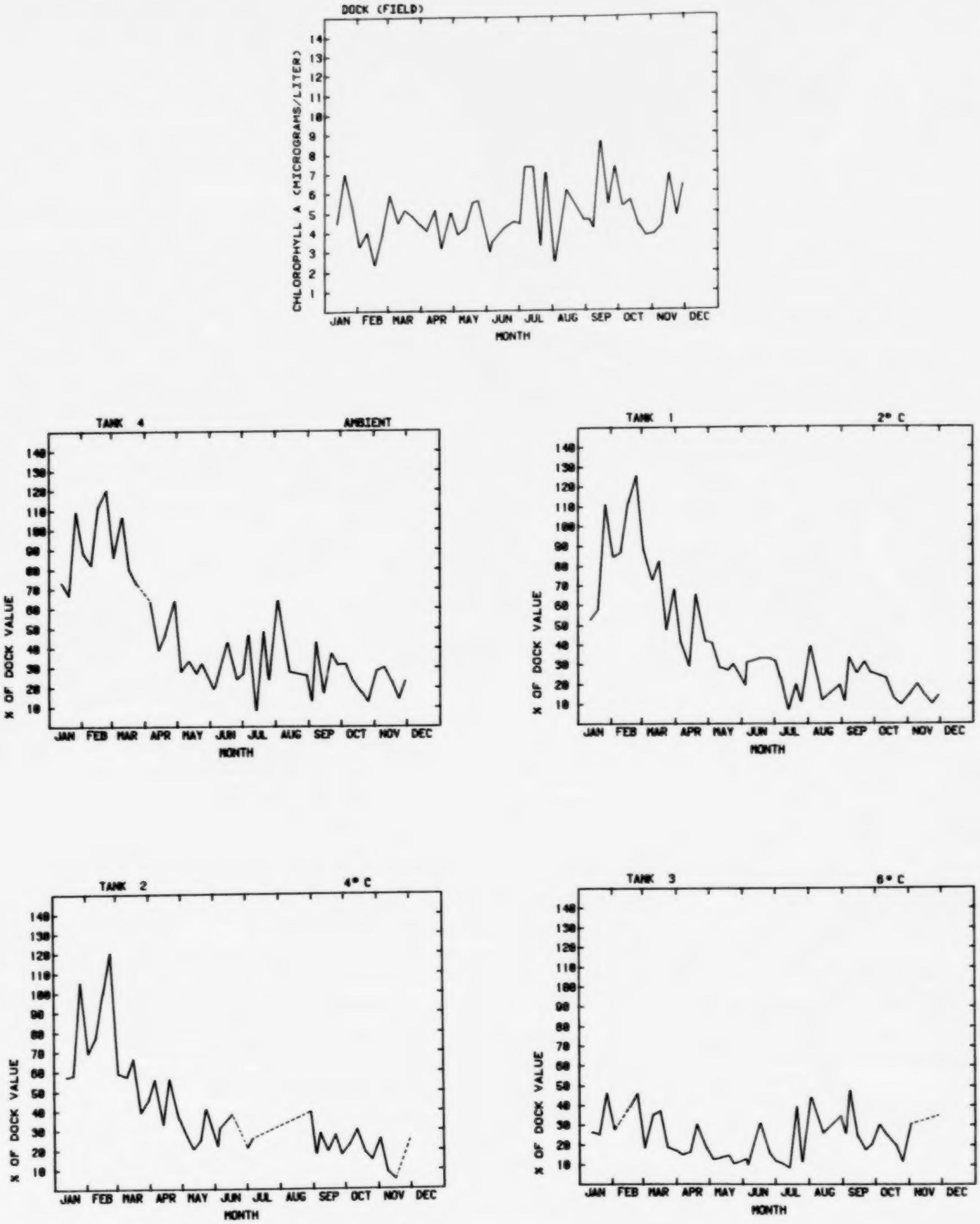

Figure 32. Weekly chlorophyll a concentrations during 1979 at the pump intake (top graph) and the percent of that concentration in the first series of experimental tanks (bottom four graphs). Dashed lines indicate no data for that period.

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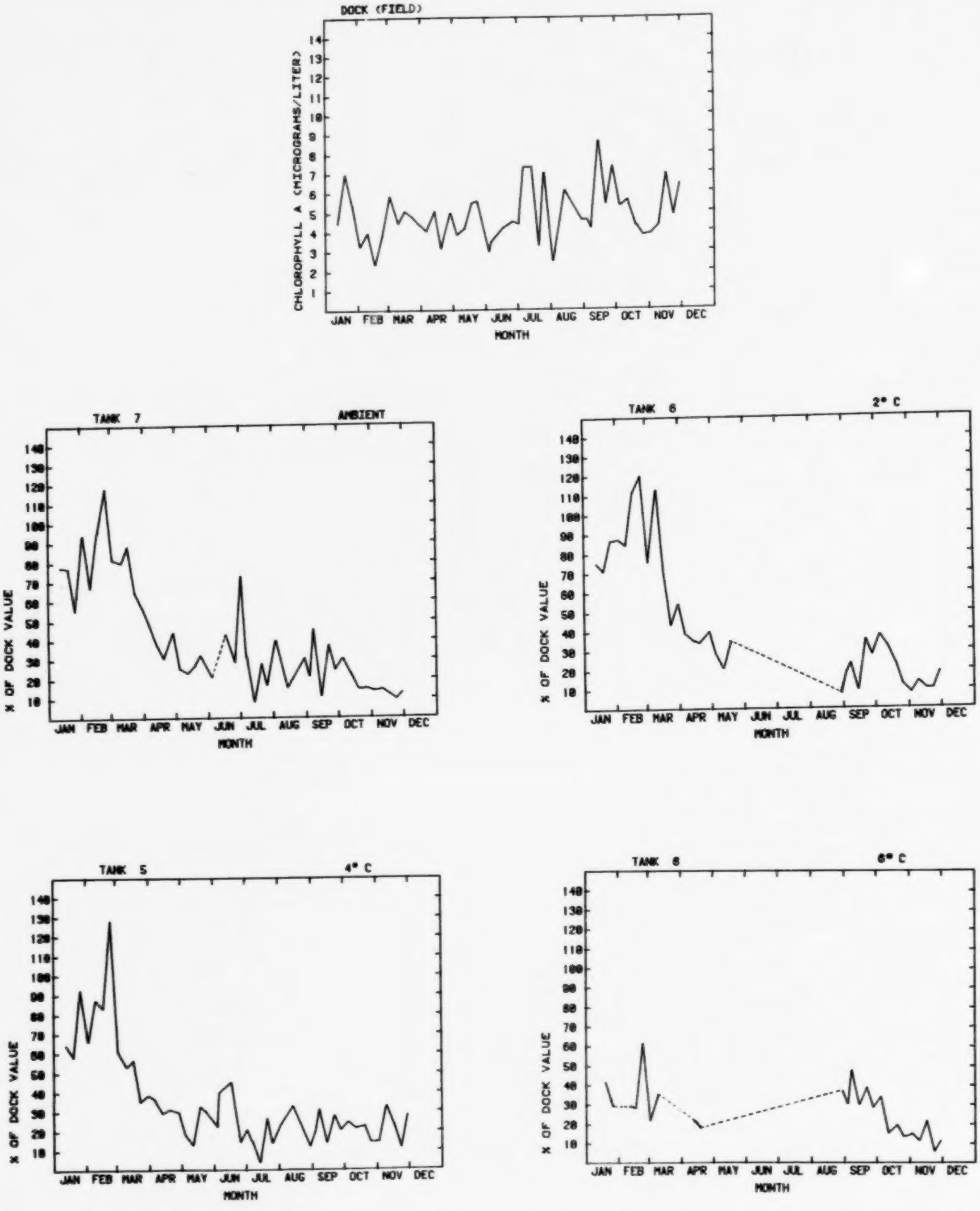

Figure 33. Weekly chlorophyll a concentrations during 1979 at the pump intake (top graph) and the percent of that concentration in the second series of experimental tanks (bottom four graphs). Dashed lines indicate no data for that period.

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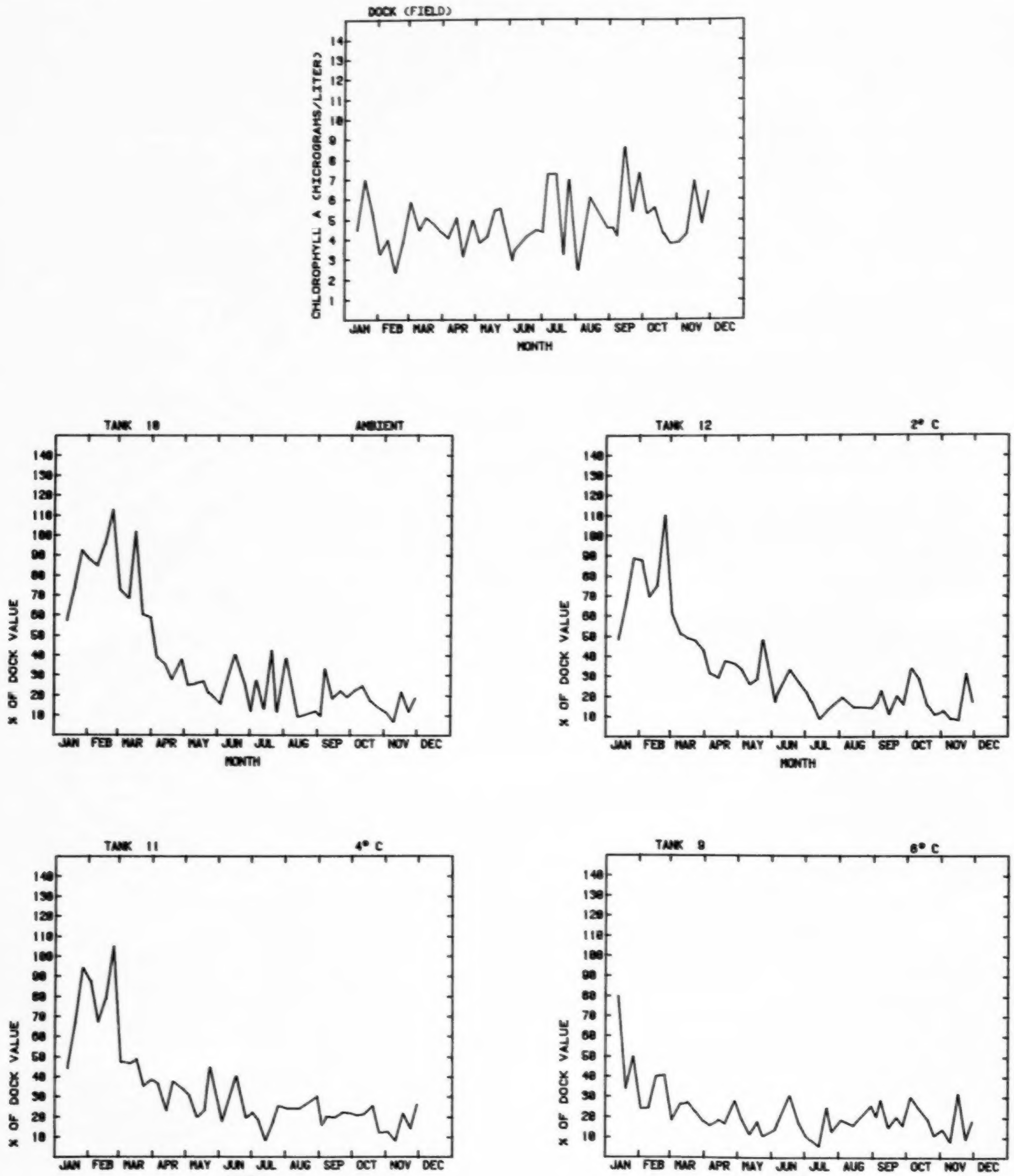

Figure 34. Weekly chlorophyll a concentrations during 1979 at the pump intake (top graph) and the percent of that concentration in the third series of experimental tanks (bottom four graphs).

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the system. The August and December experiments allowed a comparison of the effects of seasonal temperature changes on the clearance rates.

Table 30 presents results of the clearance rate experiments as a function of treatment. All the communities in the laboratory treatments had higher clearance rates than those in the field, during both the summer and winter, even though field plate communities had a greater number of species per plate and greater percent cover than the average of any of the laboratory communities. In addition, on a weight specific basis the clearance rate of field assemblages in December (21 ± 6 $ml \cdot g^{-1} \cdot hr^{-1}$) averaged only 50 percent of the clearance rate for the ambient laboratory plates (43 ± 12 $ml \cdot g^{-1} \cdot hr^{-1}$). These results are explained most simply by considering the percent cover of each taxonomic group. Table 30 shows that the field communities were dominated by tunicates (phytoplankton feeders) and anemones (zooplankton feeders) while the laboratory communities were dominated by bivalves and sponges (both phytoplankton feeding groups). Considering the laboratory groups, on a weight-specific basis in December there was a direct correlation between temperature treatment and clearance rates. Communities in the ambient temperature treatment had the lowest clearance rates (43 ± 12 $ml \cdot g^{-1} \cdot hr^{-1}$) and 6°C treatment communities had the highest (143 ± 66 $ml \cdot g^{-1} \cdot hr^{-1}$). Winter (December) clearance rates averaged 23 - 66 percent of the summer rates. Seasonal rates for field communities changed the least while rates for ambient laboratory communities changed the most.

Table 31 summarizes the significance levels for the differences between clearance rates among the laboratory communities for the four treatments measured during August and December. In general, there was a significant difference between all treatments except adjacent temperatures within a given season. In general, it was not possible to distinguish the effects of a 2°C temperature difference on clearance rates (and by extrapolation, feeding rates of suspension feeders), but a 4°C or greater temperature difference generally resulted in a significant change in clearance rates.

The influence of permanent plate organisms on the concentration of suspended food available in the laboratory tanks can be estimated by comparing the water turnover rate for the system to the clearance rates of the communities within the system. At the field location it is improbable that suspended food is ever limiting, given the strong tidal currents and the resulting thorough mixing of water, both horizontally and vertically. However, this is not the case for laboratory communities. Table 32 presents the estimates of total clearance rates by fouling communities in each of the experimental tanks as a function of treatment and month. The average flow rate through the experimental tanks was approximately 650 l/hr for each tank. Table 32 shows that a significant portion of the water flowing through each tank would be cleared of particles. Since the tanks in general were moderately well mixed as the water flowed through them, the phytoplankton concentration (chlorophyll a concentration) would not be zero even though the predicted clearance rate exceeded the average flow rates for two of the tanks (ambient and 4°C) during August. The predicted clearance rates for all tanks are much lower in December than in August, but they still represent 25 - 50 percent of the flow rate through the tank.

TABLE 30. CLEARANCE RATES (C.R.) FOR COMMUNITIES ON PERMANENT PLATES IN THE MONTHS OF AUGUST AND DECEMBER 1979. MEANS AND STANDARD DEVIATIONS ARE GIVEN. AMBIENT TEMPERATURES RANGED FROM 27°C - 29°C IN AUGUST AND 10°C - 15°C IN DECEMBER.

Treatment		Laboratory			
Parameter	Field	Ambient	2°C	4°C	6°C
August:					
Number	3	18	18	17	17
C.R. (1/plate/hr)	38 ± 5	158 ± 53	78 ± 56	167 ± 85	94 ± 61
Percent Cover	93 ± 3	81 ± 9	77 ± 12	75 ± 10	42 ± 14
Avg. # Spp/Plate	7.7 ± 0.6	6.2 ± 2.1	6.4 ± 1.9	4.8 ± 1.1	2.6 ± 1.3
Percent Cover By Group					
Bivalves	8	52	47	55	37
Sponges	11	14	7	5	0
Annelids	0	6	11	7	5
Tunicates	43	6	9	6	0
Bryozoans	6	0	0	0	0
Anemones	23	0	0	0	0
Others	2	3	3	2	0
December:					
Number	3	18	18	18	17
C.R.(1/plt/hr)	25 ± 12	37 ± 18	44 ± 23	60 ± 29	53 ± 21
C.R.(ml/g wet wt/hr)	21 ± 6	43 ± 12	58 ± 22	87 ± 29	143 ± 66
Percent Cover	94 ± 6	84 ± 9	86 ± 6	79 ± 7	55 ± 15
Avg. # Spp/Plate	7.0 ± 1.0	6.2 ± 2.0	5.7 ± 1.5	5.3 ± 1.1	3.8 ± 1.3
Percent Cover By Group					
Bivalves	1	57	51	57	48
Sponges	12	13	20	4	0
Annelids	0	4	7	11	5
Tunicates	25	6	7	0	0
Bryozoans	10	0	0	1	0
Anemones	45	0	0	0	0
Others	1	4	1	6	2

TABLE 31. SIGNIFICANCE OF TREATMENT EFFECTS ON CLEARANCE RATES OF PERMANENT PLATE BIOTA. EIGHTEEN PLATES WERE USED IN EACH TREATMENT EXCEPT FOR AUGUST 4°C, AUGUST 6°C, AND DECEMBER 6°C, WHERE N = 17. THE WILCOXON-MANN-WHITNEY RANK SUM TEST (NONPARAMETRIC) WAS USED. N.D. = NO DIFFERENCE (> 0.20).

	4°C Aug.	Ambient Aug.	6°C Aug.	2°C Aug.	4°C Dec.	6°C Dec.	2°C Dec.
Ambient Aug.	N.D.						
6°C Aug.	0.01	0.01					
2°C Aug.	0.01	0.01	N.D.				
4°C Dec.	0.01	0.01	0.20	N.D.			
6°C Dec.	0.01	0.01	0.05	0.05	N.D.		
2°C Dec.	0.01	0.01	0.05	0.10	0.01	N.D.	
Ambient Dec.	0.01	0.01	0.01	0.05	0.01	0.20	N.D.

TABLE 32. ESTIMATED CLEARANCE RATES (1/hr) BY THE COMMUNITIES IN THE EXPERIMENTAL TANKS BASED UPON THE AVERAGE CLEARANCE RATE PER COMMUNITY (TABLE 29) MULTIPLIED BY THE NUMBER OF COMMUNITIES PER TANK (SIX). AMBIENT TEMPERATURE WAS 27°C - 29°C IN AUGUST AND 10°C - 15°C IN DECEMBER.

	Ambient	2°C	4°C	6°C
August	948	468	1002	564
December	222	264	360	318

Experiments which examined diurnal variation of clearance rate of communities in the ambient tanks revealed a persistent rhythm of clearance rates (Table 33). Maximum rates usually occur in the afternoon and evening, while minimum rates occur between midnight and noon. The average minimum rate within a 24-hour period was 63 ± 12 percent of the maximum. Field communities were not intensively investigated for diurnal variations. However one preliminary 60-hour experiment, using a community which was more than five years old, showed no diurnal variation in clearance rates. It is not known whether the diurnal variation of clearance rates by the laboratory communities in ambient tanks also occurred in those at elevated temperatures, nor is it known if the observed diel variation was caused by one or more than one of the species in the community.

Results of experiments to determine the effects of phytoplankton concentration on clearance rates by communities are given are Table 34. They suggest that clearance rates by communities in ambient temperature tanks were inversely related to phytoplankton concentration. In most of the August and December clearance rate experiments the chlorophyll a concentration was between three and five micrograms chlorophyll a per liter. However, in the experimental tanks during the warmer months (April - November) chlorophyll a values were approximately one microgram per liter (10 to 30 percent of dock values, Figures 32 - 34); thus clearance rates in the laboratory would be expected to be relatively high.

TABLE 33. DAILY MAXIMUM AND MINIMUM CLEARANCE RATES (1/hr) OF FOUR COMMUNITIES FROM AMBIENT TEMPERATURE TREATMENTS. EACH VALUE IS AN AVERAGE OF FOUR SEQUENTIAL 10- TO 15-MIN REPLICATES. SIX EXPERIMENTS WERE PERFORMED EACH DAY (4-HR INTERVALS).

		Maximum		Minimum		
Plate No.	Date	C.R.(1/hr)	Time	C.R.(1/hr)	Time	Min/Max(%)
4-12	6-22	289	1200	145	0800	50
	7-5	240	0100	98	0500	41
	7-17	265	2000	200	0800	75
	7-18	242	2000	192	0800	79
	7-19	234	1600	161	1200	69
	7-20	276	1600	147	0800	53
	7-21	235	2400	191	1200	81
7-3(B)	7-24	231	2400	165	0800	71
	7-25	183	2400	119	0400	65
4-4(B)	7-31	178	1200	117	0800	66
	8-1	179	1200	132	0800	74
	8-2	192	2000	103	0800	54
	8-3	208	2000	145	0800	70
10-3(B)	8-6	217	1600	97	2000	45
	8-7	268	1600	148	2400	55
	8-8	261	1600	179	0800	69
	8-9	208	1600	123	0400	59
	8-10	211	2400	126	0800	60

Mean ± S.D. ratio (%) of minimum to maximum = 63 ± 12%.

TABLE 34. INFLUENCE OF PHYTOPLANKTON CONCENTRATION ON COMMUNITY CLEARANCE RATES OF AMBIENT EXPERIMENTAL TANKS (PLATE 4-11B)

Date	Concentration of Phytoplankton* (ug/1)	Clearance Rate** (1/hr)
6-19	8.5	69 ± 18
6-20	5.5	127 ± 4
6-21	2.0	105 ± 31
7-3	8.1	53 ± 11
7-4	5.8	85 ± 30
7-5	1.8	104 ± 6
7-11	10.4	61 ± 12
7-12	5.9	173 ± 38
7-13	2.2	194 ± 58

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* Estimate based on *in vivo*/*in vitro* correlation

**Each rate is an average of four sequential 10- to 20-min experiments.

SECTION 6

DISCUSSION

THE LABORATORY SYSTEM

The experiments described here investigated the consequences of long-term, low-level elevations in water temperature on the structure of a marine epifaunal (fouling) community. As previously described these experiments required isolating communities in a laboratory system. A comparison of field data with data from the laboratory 0°C treatment (ambient temperature) showed that the laboratory system had a dramatic effect on recruitment and community structure; therefore, discussion of the effects of temperature additions on the fouling community must compare elevated temperature treatments with laboratory ambient temperature treatments and not with field treatments. On the other hand, communities recruited in the laboratory were composed of approximately equal numbers of species (albeit different species) as in the field and these laboratory plate species were all common members of the assemblage of epibenthic species found in Beaufort, North Carolina.

Initial recruitment experiments during the winter of 1976 - 1977 indicated that position of the tanks caused no differences between tanks in recruitment of barnacles (the only species of which there was significant recruitment). Therefore data were pooled according to experimental treatment (three tanks for each of the four treatments).

During the course of the experiment, there was a significant difference between the recruitment of species on field and laboratory 0°C treatment plates in 76 percent of the 270 cases. The patterns of these differences in recruitment were varied: for some there was a greater recruitment in the laboratory than in the field, with other species there was greater recruitment in the field, and in some cases there were time periods when recruitment was the same on both field and laboratory plates.

The species composition on laboratory 0°C plates as compared to composition on field exposed plates was also very different. Only one species (the oyster Crassostrea virginica) was a significant member of both field and laboratory communities. Cluster analysis showed that communities on field and laboratory plates were different even though the average number of species per plate and the species diversity of the communities were similar in field and laboratory 0°C treatments. Finally, there was significantly greater unoccupied space on laboratory plates than on field plates.

Some of the differences between laboratory and field conditions might be explained by the differences in water quality caused by the physiological activities of animals on the plates. Results of clearance rate experiments showed that the rate of flow of water was not adequate to maintain field concentrations of suspended material (phytoplankton) in the laboratory 0°C treatment tanks except during the middle of the winter. Most of the members of the fouling community depend upon suspended material for food and upon suspended larvae for recruitment. Thus the laboratory communities probably influenced both recruitment and/or growth of species through the suspension feeding activities of the communities themselves.

The laboratory system provided a technique for investigating the influence of chronic increases in water temperature on recruitment and growth of a number of species in a fouling community. Increasing temperatures often either had no effect or caused an increase in the number of recruits of the individual species. In several cases, there was an increase in 2°C and 4°C treatments, but a decrease at 6°C. The timing of recruitment also was altered in several cases, so increasing temperature resulted in earlier maximum recruitment of spring and early summer recruiting species.

The effects of increasing temperature on percent cover varied depending upon the individual species. However, in the 6°C treatment a significant decrease in percent cover of many species occurred during the late summer when the ambient water temperatures were approximately 30°C. For some species, this created seasonal cycles in percent cover which were not observed at ambient temperatures. In general, an increase of 2°C produced little change in percent cover, while an increase of 6°C had dramatic effects. The effects of 4°C were intermediate between 2°C and 6°C effects.

INDIVIDUAL SPECIES

Table 35 is a list of the 31 taxa that occurred as 10 or more individuals at least once on larval recruitment, or with 10 percent or greater cover at least once on permanent plates at some time during the three years of the experiment, or both. The list includes seven species whose southern limit of distribution is North Carolina or South Carolina, five whose northern limit is North Carolina, and 16 species that range both north and south of North Carolina. All species have been reported frequently from North Carolina and most are considered common members of the epibenthic or fouling community at North Carolina (Kirby-Smith and Gray 1977). No exotic species or range extensions of species were recorded on either the larval recruitment or the permanent plates.

The occurrence data presented in Table 35 show that four species (two sponges, one coelenterate, one mollusc) occurred in significant numbers on permanent plates but were not recorded on recruitment plates. Two species (a hydroid and a bryozoan) were censused on the recruitment plates but not on the permanent plates. The vast majority of species (24) were recorded in significant numbers on both the recruitment and the permanent plates.

TABLE 35. LIST OF SPECIES OCCURRING IN SIGNIFICANT NUMBERS ON RECRUITMENT (R) AND/OR PERMANENT (P) PLATES WITH THEIR GEOGRAPHICAL DISTRIBUTION

Group	Species	Occurrence (R)	 (P)	Distribution
Porifera	*Aplysilla sulfurea*		X	West Indies to North Carolina
	Haliclona loosanoffi		X	North Carolina to Cape Cod
	Halichondria bowerbanki	X	X	North Carolina to Bay of Fundy
	Leucosolenia canariensis	X	X	Cosmopolitan
	Leucosolenia sp.	X	X	
Hydrozoa	*Eudendrium ramosum*	X	X	South Carolina to Labrador
	Pennaria tiarella	X	X	West Indies to Maine
	Tubularia crocea	X		Florida to Bay of Fundy
Anthozoa	*Aiptasia pallida*		X	North Carolina to Cape Cod
	Astrangia danae	X	X	Florida to Cape Cod
	Diadumene leucolena	X	X	North Carolina to Cape Cod
Bryozoa	*Anguinella palmata*	X	X	Brazil to Cape Cod
	Bugula avicularia	X	X	Brazil to New England
	Bugula neritina	X	X	Brazil to North Carolina
	Electra monostachys	X		Brazil to Maine
	Schizoporella errata	X	X	South Carolina to Massachusetts
Annelida	*Hydroides dianthus*	X	X	West Indies to Massachusetts
	Sabellaria vulgaris	X	X	Georgia to Cape Cod
	Spirorbis borealis	X	X	North Carolina through Canada
Mollusca	*Argopecten irradians*	X	X	Gulf of Mexico to Canada
	Crassostrea virginica	X	X	Gulf of Mexico to Canada
	Geukensia demissa	X	X	Florida to Canada
	Modiolus americanus		X	Caribbean to North Carolina
Cirripedia	*Balanus* spp.	X	X	
Amphipoda	*Corophium acherusicum*	X	X	Cosmopolitan (warm temperate)
Urochordata	*Ascidia interrupta*	X	X	West Indies to North Carolina
	Botryllus schlosseri	X	X	Florida to New England
	Molgula manhattensis	X	X	Gulf of Mexico to Canada
	Perophora viridis	X	X	West Indies to New England
	Styela plicata	X	X	Brazil to North Carolina
	Unknown tunicate	X		

Two species of sponge, *Haliclona loosanoffi* and *Halichondria bowerbanki*, occurred with significant percent cover on permanent plates by the end of the experiment. In those communities in which they became established, they were able to outcompete the dominant *Crassostrea virginica* for space. The data suggest that if the experiment continued, some of the communities in the 0°C, 2°C, and perhaps the 4°C treatments would have become dominated by these sponges; yet these sponges appeared unable to invade communities at 6°C. Sutherland and Karlson (1977) reported seven major groups of species on fouling communities at Beaufort, N.C. Of the seven groups of species, one was dominated by *Haliclona* and another by *Halichondria*. Sponges are apparently slow to appear on plates, but are good competitors for space once established.

Hydroids, which are seasonally important members of the fouling community at Beaufort (McDougall 1943, Sutherland and Karlson 1977), recruited infrequently and in low numbers on laboratory plates and never became significant members of the permanent plate assemblages. It was apparent that the laboratory system, in some unknown manner, prevented the establishment of the hydroids that are important in field communities. On field plates, *Tubularia crocea* was recruited every spring during the three years and *Eudendrium ramosum* was recruited every summer. *E. ramosum* occurred only once with greater than 10 percent cover on field permanent plates.

Anthozoans were never counted in significant numbers as recruits in the field or in the laboratory. However, the anemones *Aiptasia pallida* and *Diadumene leucolena* and the coral *Astrangia danae* did occur frequently on both field and laboratory permanent plates. By the end of the experiment, *A. pallida* had become the dominant species in the community on two of the three field plates. In the laboratory not only did all anthozoans occur with extremely low percent cover, but they were adversely affected by the 6°C above ambient temperature treatment. Temperatures of 2°C above ambient did not appear to be harmful, but may have resulted in slightly increased percent cover for *A. pallida* and *D. leucolena*.

Bryozoans were an important group on both field and laboratory plates. *Schizoporella errata* recruited seasonally on both field and laboratory 0°C plates. Sutherland (1978) has shown that the success of *S. errata* on plates depends upon larval availability when free space is available. It can occupy up to 100 percent of the space on a newly submerged plate and it will resist recruitment of other species once it is established. However, *S. errata* is unable to invade space occupied by other species. Sutherland (1978) also observed that percent cover of *S. errata* decreased on the plates on which it was dominant from approximately 100 percent cover to near zero percent during a three-year period. On field plates in this experiment *S. errata* decreased in percent cover steadily from a mean of 79.9 percent at the first sampling period to less than one percent by the end of the experiment, which confirmed Sutherland's 1978 results. Even though *S. errata* recruited well in the laboratory, it never became established on permanent plates in either Series "A" or "B" and thus was never a significant member of the laboratory community.

Two species of the bryozoan genus *Bugula*, *B. neritina* and *B. avicularia*, were important on both field and laboratory plates. *B. neritina* recruited better on field than laboratory 0°C plates. Increasing temperatures in the laboratory generally caused an increase in recruitment. In the permanent plate communities *B. neritina* also was much more important on the field plates than on the laboratory plates. In contrast to what was observed on recruitment plates in the laboratory, the perent cover of *B. neritina* on permanent plates in the laboratory was little influenced by temperature except that the 6°C permanent plates had significantly fewer colonies than the other treatments. *B. avicularia*, on the other hand, recruited better in the laboratory than in the field with somewhat better recruitment at 6°C than at the other temperature treatments. There was also an indication that increasing temperatures may have resulted in a slightly earlier spring recruitment of this species. *B. avicularia* occurred with greater percent cover in the laboratory than in the field, but temperature had little effect upon the percent cover values.

McDougall (1943) found that *B. neritina* was one of the most abundant organisms on pilings in Beaufort. He found *B. avicularia* to be "fairly common" but much less plentiful than *B. neritina*. The field plate data reported here agree with this observation. *Bugula* is an erect genus, having a bushy, tree-like appearance. A casual observer would probably conclude that *Bugula* was much more abundant than indicated here, since only points of basal attachment were counted as percent cover. If the volume of space occupied by the whole colony were counted, then the importance value of *Bugula* in the community would increase dramatically. The functional importance of *Bugula* as a species in the fouling community is probably greater than is indicated by area of attachment to primary space.

Two species of serpulid polychaete worms were important in their percent cover of primary space in the communities in this study: *Spirorbis borealis*, a very small worm which builds a spiral tube (3 mm in diameter), and *Hydroides dianthus*, a moderate-sized polychaete with a straight or unpredictably bent tube (up to approximately 75 mm long). *H. dianthus* recruited on field plates in relatively large numbers during all three summers of the experiment. It recruited on laboratory plates with the same regularity, but at much lower numbers compared to field plates. Increased temperature in the laboratory did not have a predictable effect upon the numbers of *H. dianthus* recruited. Although higher temperature treatments (4°C and 6°C) resulted in an earlier peak in recruitment in 1978 and 1979, *H. dianthus* had a fairly constant percent cover on all permanent plates in all treatments. Therefore, neither the laboratory system nor increased temperatures had a significant effect on percent cover by this species, making it the least affected of all species studied in its response to experimental conditions. From these data it appears that *H. dianthus* became established during the early stages of community development and that little recruitment occurred to older communities. This implies that *H. Dianthus* is capable of living for several years, even though it may mature sexually after a couple of months (McDougall, 1943).

Spirorbis borealis had extremely high rates of recruitment, especially in the laboratory. Along with the oyster Crassostrea virginica it was the most dominant occupier of space on permanent plates in the laboratory. Spirorbis was never counted on the field permanent plates. Its prominence on the laboratory plates probably results from its short planktonic life. Knight-Jones (1951) found that S. borealis larvae are planktonic for only 15 min to two hours after being released from the adult and that they preferentially settle in the vicinity of adults and other newly settled larvae. Hence, once S. borealis became established in the laboratory system, the permanent plates and the experimental tank walls were probably the primary sources of new individuals for the permanent plates.

While S. borealis was not a significant member of field plate communities in this or previous studies (Sutherland and Karlson, 1977; McDougall, 1943), it does occur commonly on hard substrate in the Beaufort area. The success of S. borealis in the laboratory could be due to the absence of fish and crab predators which may feed on these organisms in the field. In the laboratory the success of Spirorbis, expressed as percent cover, was greatest at 2°C and 4°C with somewhat reduced cover at 0°C and significantly lower percent cover at 6°C. In 1979 a decrease in percent cover on the 0°C, 2°C, and 4°C permanent plates (but not on the 6°C plates) coincided with increased frequency of cleaning of tanks. In numbers of recruits, there was a decrease in 1979 on the 4°C and 6°C plates, little change from 1978 at 2°C, and an increase at 0°C. Thus it is not clear that the decreasing percent cover noted on 0°C, 2°C, and 4°C permanent plates was necessarily the result of increased frequency of tank cleaning.

Crassostrea virginica, the common eastern oyster, was the single most important species on laboratory permanent plates. Together with Spirorbis borealis it characterized the community present on most of the plates in all laboratory treatments. This is reflected in the cluster analysis results. C. virginica was recruited more or less evenly on all laboratory plates; recruitment on field plates may have been slightly greater. On laboratory permanent plates it occurred with relatively high and continuous percent cover at 0°C, 2°C, and 4°C throughout the experiment. The percent cover by oysters in the 6°C treatments was also high and continuous in the summer of 1977 when the oysters had just settled and were relatively small. However, in 1978 when the oysters were larger, there was a late summer decrease in percent cover at 6°C caused by increasing mortality. In the winter and spring of the third year (1979) oysters began increasing in percent cover on 6°C plates, probably because of the growth of small oysters. A decrease followed on the 6°C plates in the late summer of 1979. Oysters in the field communities had much lower percent cover, probably because of predation of fish, crabs, and molluscs. Sutherland and Karlson (1977) and Karlson (1978) found low percent cover by oysters in the field; however, they identified a different species of oyster (Ostrea equestris). Although all oysters on field plates in this study were counted as Crassostrea virginica, it is possible that some smaller individuals were misidentified. No Ostrea equestris were identified on any plates.

Another bivalve mollusc, Geukensia demissa, the Atlantic ribbed mussel, occurred in significant and rather constant abundance in all laboratory treatments, but not on field plates. This species was never counted in significant numbers on larval recruitment plates. The persistently greater percent cover on Series "A" than on Series "B" laboratory plates suggested that individuals that were recruited during the early summer of 1977 on the Series "A" plates remained there with only slight mortality. The data also suggest that new recruits were not added during the following two years; that is, growth of individuals was balanced by mortality. There were no obvious effects of increasing temperature on percent cover by *G. demissa*.

Barnacles are often considered to be the most opportunistic group of organisms in shallow, marine, epibenthic communities, since they settle in large numbers, grow rapidly, reproduce and die as they are outcompeted for space by other organisms. In this study, data for recruitment and percent cover by barnacles (*Balanus* spp.) are difficult to interpret since separate species were not identified. It is likely, at least on field plates, that these species were a mixture of *B. eburneus*, *B. amphitrite*, *B. tintinnabulum*, and *B. improvisus* (McDougall 1943, Sutherland and Karlson 1977). The number of barnacles recruited in the laboratory was two orders of magnitude lower than the number settling on field plates. It is not known whether there were differences in species composition of recruits between the field and laboratory plates. Barnacles were seasonally important members of the field plate communities with maximum percent cover of 10 - 20 percent occurring in the spring and autumn. In contrast, during midsummer and midwinter minimum percent covers of less than one percent occurred. Barnacles were important in all laboratory treatments at the first census of Series "A" plates (spring 1977). The Series "B" plates were submerged during the late summer when barnacle settlement was low and thus they never had a significant percent cover by barnacles. On Series "A" plates percent cover by barnacles decreased rapidly during the first four months and remained, in general, below one percent cover for the rest of the experiment.

The amphipod *Corophium acherusicum* was recruited in large numbers in the laboratory but in much smaller numbers in the field. *C. acherusicum* occurred infrequently and in low numbers on the field permanent plates, which confirmed observations of Sutherland and Karlson (1977). However, *C. acherusicum* has been observed in dense mats on pilings at Beaufort, N.C. (Karlson 1978) and on hard substrate in thermal discharge outfalls (Naylor 1965b, Young and Frame 1976). From the spring of 1977 through the spring of 1978 there was a relatively high periodic recruitment and a continuously high percent cover by *C. acherusicum* in the laboratory on the 0°C and 2°C plates. In the late summer of 1977 at 4°C and 6°C, percent cover declined dramatically but increased again in the winter and spring of 1978. In the summer of 1978 there was a dramatic decrease of *C. acherusicum* in all treatments in the laboratory. In the winter of 1978 - 1979, percent cover increased dramatically at 6°C but not in the other treatments. In general, *C. acherusicum* was an important member of the community on most laboratory permanent plates during the first year of the experiment, but became less important (in general) and more variable during the second and third years.

Tunicates are important members of the fouling community at Beaufort, N.C. McDougall (1943) observed the same five species which were recorded here. Sutherland and Karlson (1977) recorded four of these five; they did not observe Perophora viridis. The two larger species, Styela plicata and Ascidia interrupta, recruited almost exclusively on field plates. Two other species, Molgula manhattensis and Perophora viridis, recruited infrequently but in moderate abundance on laboratory plates and very infrequently on field plates. The encrusting tunicate Botryllus schlosseri recruited with low frequency on field and laboratory plates and occurred in very low abundance on field permanent plates as compared with laboratory permanent plates. The identification of young solitary tunicates is difficult and therefore a recruitment category was established which was called "unknown tunicate." The coincidence and timing of maximum recruitment of the "unknown tunicate" with peak recruitment of the identifiable species and subsequent percent cover by the identifiable species on permanent plates suggest that in the laboratory "unknown tunicate" was Ascidia interrupta while in the field larval plates it was predominantly Styela plicata. In the field, percent cover of these two species of solitary tunicates undergoes large fluctuations through time (McDougall 1943, Sutherland and Karlson 1977). Both species tend to grow rapidly and become the most important species in the community based on percent cover during late spring and early summer. Then in the summer most individuals die and are lost by sloughing off the substrate, leaving few individuals by autumn. This cycle also was observed in this study on field plates. Increased temperatures in the laboratory caused a decrease in recruitment and percent cover of all species of tunicates present; this was particularly evident at 6°C as compared to 0°C.

COMMUNITY DEVELOPMENT

The effects of chronic low-level thermal additions on development of the fouling community have been assessed here using several techniques including number of individuals recruited, percent unoccupied space, number of species per plate, diversity of percent cover data, and cluster analysis for identification of species groups as a function of treatment.

There are many techniques which have been used in quantitative community ecology; however, those used in this study were selected as being the most useful given the type of community, the experimental perturbations, and the type of data collected. Data on the number of individuals of each species which were recruited provided information on the pool of species which might appear as adults in the permanent community and the influence of thermal additions on recruitment to communities. Estimates of percent unoccupied space on permanent community plates provided information on the availability of primary space in the permanent communities for these recruits. The number of species per plate and the diversity of the percent cover data were both useful measures of the community structure which allowed comparisons of effects among the different treatments. Cluster analysis of counts and percent cover data provided a technique for examining the degree of similarity among communities exposed to different treatments. The cluster analysis technique is limited in that it examines only abundance of each species relative to each other and it is not influenced by absolute density of individuals. The differences among "clusters of species" (or communities) is most affected by the presence or absence of dominant species in any one treatment.

From recruitment data it was noted that a 2°C change in temperature resulted in significant differences in recruitment in 40 percent (0°C - 2°C), 38 percent (2°C - 4°C), and 44 percent (4°C - 6°C) of the cases in which there was significant recruitment of any one species. At 4°C there were 52-percent (0°C - 4°C) and 55-percent (2°C - 6°C) differences. However, in the results it was noted that increasing temperatures by 2°C and 4°C had little or no effect upon the percent unoccupied space. At 6°C there was a significant increase in the percent of unoccupied space in the late summer which undoubtedly resulted from the high mortality and sloughing off of dead and dying organisms. In general, there was a gradual reduction in the average number of species per plate with increasing temperature. Although the decrease over a 2°C interval would be difficult to distinguish (note overlapping standard deviation when comparing graphs in Figure 25) the decrease when comparing 0°C with 6°C treatments is clearly significant. The influence of temperature on diversity (calculated from percent cover data) was more or less the same as that observed for the number of species per plate with a significant reduction in diversity in midsummer at 6°C and a recovery in winter and spring. The cluster analysis of percent cover data suggested that (1) field communities were very different from laboratory communities, but (2) within the laboratory the community differences that did exist were not temperature related, and (3) the structure of most of the laboratory communities was similar regardless of temperature. Cluster analysis of larval recruitment data showed that field plates recruited a community that was very different from that in the laboratory. In the laboratory the recruitment species groups changed with time and were seldom related to temperature treatment.

Based on this general summary of results, the following discussion deals with the details of fouling communities in general and the community at Beaufort, N.C., in detail.

The study of the development of marine epifaunal or "fouling" communities has centered around investigations of competition for space (point of attachment) by sessile organisms which are recruited to a substrate from free-swimming planktonic larvae. These species subsequently interact with each other as they grow and interact eventually with potential larval recruits which may attempt to settle on substrate. Sutherland (1974, 1977, 1978, 1981) and Sutherland and Karlson (1973, 1977) have studied community structure of the fouling community at Beaufort, N.C., for eight years. During that period their concepts of the factors that determine the structure of the community have also evolved. At first Sutherland (1974) argued that time of year (and perhaps time of month) when the substrates were made available determined the structure of the resident adult assemblage; this resulted in multiple stable communities having different structures (Lewontin 1969). Sutherland and Karlson (1977) later concluded that there was no stable assemblage and that succession in the classical sense did not occur in the fouling community. Sutherland (1981) recently concluded that whether stable assemblages occurred depends upon which assemblage is discussed, the specific perturbations to the community, and the time scale of the perturbations. The results of the study reported here may be interpreted with reference to Sutherland's work since the communities studied are the same. The specific questions being asked concern the community changes which may result from (1) the laboratory seawater system and (2) thermal additions. The two indices of community structure which Sutherland found to be relatively predictable through time, even in the face of changing species composition, were the amount of free space on the substrate available for larval recruitment and the average number of species per plate.

Under field conditions, Sutherland and Karlson (1977) found that percent unoccupied space decreased rapidly from 100 percent on newly submerged plates to near zero percent after several months. Thereafter, there was an annual fluctuation of unoccupied space from a high of 20 - 60 percent in the late summer and early autumn, caused by sloughing off of attached species (mainly the two tunicate species), to a low of nearly zero percent unocuppied space for the remainder of the year. In the present study the mean of unoccupied space on field plates was never greater than 10 percent; this occurred in late summer and autumn). In the spring there was nearly zero percent unoccupied space. Percent unoccupied space in the laboratory 0°C plates was much greater and became less variable through time than that on the field plates. During the first year and a half the unoccupied space ranged from a maximum of greater than 50 percent to a minimum of 10 percent. During the latter part of the experiment the percent unoccupied space on the 0°C laboratory plates became more or less constant at between 10 - 20 percent. At no time did the percent unoccuppied space approach zero percent. The larger tunicates (Styela and Ascidia) were not significant occupiers of space on laboratory plates; hence the summer - autumn sloughing of organisms which is common on field plates did not occur in the laboratory. Predominant species in the laboratory communities were the oyster Crassostrea virginica and a serpulid polychaete, Spirorbis borealis. Photographs of the 0°C plates showed that most of the unoccupied space after the first year of the experiment was caused by the death of oysters. A continuous but low-level mortality of oysters thus appears to have been responsible for maintaining the 10 - 20 percent unoccupied space. Once open space became available, it is possible that the grazing activities of the limpet Diodora cayenensis may have kept the surface clean of newly settled organisms. This limpet was removed from plates when seen, but small specimens and individuals which were hidden under the canopy of other organisms may have been overlooked. The amphipod Corophium acherusicum, which was a common member of the laboratory communities, also may have helped to keep the unoccuppied space higher than it might have been in their absence. This species has a mud tube attached to the substrate and individuals come out of the tube and move freely over the surface of the plate, possibly grazing upon and hence removing newly settled organisms.

During the late summer at temperatures 6°C above ambient, unoccupied space increased to greater than 60 percent. During the same period the 4°C communities had 10 - 30 percent unoccupied space, which was similar to that in the 0°C and 2°C treatments. The high percentage of unoccupied space on 6°C plates was the result of high mortality of the larger, one-year old, oysters. Ruddy et al (1975) have reported on the influence of thermal additions, averaging 9°C above ambient temperatures, on the biochemical "condition" and growth of oysters in Connecticut. They found that in the winter and spring thermal additions were beneficial to oysters. In the midsummer (at 30°C in the thermal effluent) these oysters might have been slightly negatively influenced. These results of Ruddy et al (1975) are similar to those reported here except that negative impacts on oysters in midsummer were not observed until temperatures reached 36°C. This exception may reflect the difference in the physiology of more southern populations which naturally experience higher temperatures. Results similar to those of Ruddy et al (1975) were noted by Tinsman and Maurer (1974) for oysters held in a thermal discharge in Delaware.

The average numbers of species which occurred on field and laboratory 0°C plates were similar to those observed by Sutherland and Karlson (1977) on field plates in Beaufort, N.C. These workers concluded that an equilibrium number of species (8 - 10) occur on these plates. In the laboratory at 0°C, the maximum number of species occurred in the spring and the minimum occurred during the late summer. Increasing temperature resulted in a decrease in the average number of species, particularly at 6°C. Species diversity of epibenthic communities has been measured in several studies related to thermal addition. In field studies in the temperate zone, the species number and/or diversity of communities exposed to heated effluent is generally greater in the spring, fall, and winter and less in the summer when compared to nonheated intake water (Nauman and Cory 1969, Young and Frame 1976). In tropical or subtropical shallow marine systems the number of species and/or diversity decreases with increasing temperature (Thorhaug et al 1971, Kolehmainen et al 1974). In both temperate and tropical marine systems total biomass and/or productivity generally increases with increasing temperature beyond the point where species number and/or diversity decreases. In the only previous investigation of effects of increased temperature on epibenthic communities in a laboratory flow-through system (Wolfson 1974), it was found that increasing temperature (+3°C) during seasons of low temperatures (spring) did not affect species diversity, but that elevated temperatures in the summer caused a decrease in diversity below controls. In the study reported here increasing temperature up to 4°C had little effect on species diversity over a 30-month period. However, at 6°C above ambient temperature there was a large decrease in diversity during the late summer, which resulted in an annual cycle of diversity not seen in the other laboratory treatments. The effect of increased temperature (particularly 6°C above ambient) was to cause an increase in the number of species recruited in winter and a decrease in summer. The pattern of recruitment also was changed from the summer maximum and winter minimum observed on both field and 0°C laboratory plates to a spring maximum and summer and winter minima at 6°C.

One of the most interesting results of this study was that in spite of the large influence of temperature on many individual species and the large initial differences between the "A" and "B" series, the structure of the final communities was shown by cluster analysis not to be predictably related to the respective temperature events represented by these two series of plates, nor by their time of submergence. Throughout the experiment, the communities in all four laboratory temperature treatments and both series became more and more similar to each other. It is possible that had the experiment continued for another year, two community types might have appeared. One community type would have been the same as the one that existed on most laboratory plates, that is, the oyster-dominated community, and would have continued to be present in all four treatments. The other community that was becoming established on some plates was one dominated by sponges; this community occurred in all treatments except the 6°C.

In summary, cluster analysis showed that the laboratory system produced a community which was significantly different from that in the field. Within the laboratory, increasing temperatures did not alter the basic community structure (as defined by percent cover) because the dominant species at 0°C, _Crassostrea_ _virginica_ and _Spirorbis_ _borealis_, were also dominant in the 2°C, 4°C, and 6°C treatments. However, increasing temperature did have a negative impact on the number of species and species diversity on both recruitment plates and permanent community plates. This effect, evident at 4°C, was most pronounced at 6°C. At 2°C there was no discernible effect of temperature on number of species or diversity.

FLOW RATES AND FOOD CONSUMPTION

Most of the species that make up the fouling community are suspension feeders that use the phytoplankton and zooplankton suspended in the water for their source of energy. In this study the food supplied to laboratory communities was a function of the flow rate of water through the experimental tanks. Flow rates ranged from 10 - 12 liters per minute for each tank. Since each tank had six permanent plate communities, approximately two liters of seawater per minute were available for each community plate. Although this flow might appear sufficient to supply food for the animals in the community, the data on clearance rates and chlorophyll _a_ suggest that this probably was not the case. Clearance rates for laboratory plates were variable and temperature dependent; however, in the late summer clearance rates generally were approximately 100 percent of the flow rates and, in late autumn, 50 percent of the flow rates. Except for midwinter, chlorophyll _a_ values in experimental tanks were reduced by feeding activities of communities to a low of 10 - 30 percent of field values. The influence of food availability on the growth of most suspension feeders in this community is unknown; however, Kirby-Smith (1972) found that growth of the scallop _Argopecten_ _irradians_ was reduced when chlorophyll _a_ concentrations dropped below 60 percent of that available in the field. Species in the study community may be more or less sensitive than scallops to changes in suspended materials in the water. The question whether communities in the different temperature treatments would have been more distinct from each other had they not been food stressed remains to be answered. However, food limitation does represent an important variable which could influence these results. This problem may be mitigated in future studies by increasing the rate of water flow through the tanks and decreasing the feeding demand by having fewer replicate communities in each tank.

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